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*ENTOMOLOGICAL SERIES—BULLETIN No. 2*

DEPARTMENT OF AGRICULTURE

MYSORE STATE

# THE JOLA OR DECCAN GRASSHOPPER

*(Colemania sphenarioides, Bol.)*

BY

LESLIE C. COLEMAN, M.A., PH.D.

*Mycologist and Entomologist to the Government of Mysore*

219217

BANGALORE:

PRINTED AT THE GOVERNMENT PRESS

1911

PRICE ONE RUPEE.

*Plate I.* *Frontispiece.*

## *EXPLANATION OF PLATE I.*

FIG. 1.—Nymphs of the Jola Grasshopper (*Colemania sphenarioides*, Bol.) feeding on a young plant of jola (*Andropogon sorghum*, L.)

FIG. 2.—Top of an almost mature jola plant showing damage done to leaf and head. An adult male grasshopper is feeding on the head.

FIG. 3.—Nymph of the third instar showing colour variation, greenish, tinged here and there with red.

FIG. 4.—Adult female grasshopper laying eggs.

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# FOREWORD.

This bulletin aims to give as complete information as possible about a very serious insect pest. As the pest is a new one, and as practically nothing has been published with regard to it, I have thought it wise to give a detailed scientific description of the insect and a full account of its life-history, in addition to the discussion of what are commonly but erroneously considered more practical matters. A popular account is being prepared for issue as a Kanarese bulletin.

The facts, as here given, are the results of observations and experiments extending over about two years. In this connection, I wish to express my appreciation of the efficient service rendered by B. C. Shantappa, formerly Fieldman but now Agricultural Inspector in this Department, in the carrying out of practical measures planned by me.

The coloured plates are from paintings made by M. Ranganayakalu, Artist of this Department. All photographs as well as the original drawings for most of the other figures were made by the author.

In conclusion, I wish to express my thanks to Mr. C. H. Yates, Superintendent, Government Press, for the great care he has taken in the printing of text and plates.

Bangalore,
*June 1911.*

Leslie C. Coleman.

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# THE JOLA OR DECCAN GRASSHOPPER

## (*Colemania sphenarioides, Bol.*)

THE Deccan Grasshopper is a new and serious agricultural pest in Mysore. It is to be considered serious not only on account of the damage it has already done in the areas where it has gained a footing, but also on account of its possibilities for the future. So recent is this pest that practically nothing has, as yet, been published with regard to it. The first printed reference to it occurs in a note by Mr. Maxwell Lefroy, Imperial Entomologist, published in the Journal of the Bombay Natural History Society, Vol. XIX, No. 4, 1910, p. 1007. In this note, he suggests that the popular name "Deccan Grasshopper" be applied to the insect as indicating its habitat. This name is, on the whole, a suitable one, although this grasshopper appears to occupy but a fraction of the area known as the Deccan. In Mysore, it would be, perhaps, better known as the Jola Grasshopper, for here it occurs, as yet, only in those areas where jola (*Andropogon sorghum*) is the staple cereal crop and it is, therefore, to this crop that the most extensive damage is done.

In April 1910, specimens of this grasshopper, collected the previous year in the neighbourhood of Honnali, Shimoga District, were sent to Prof. Ignacio Bolivar, one of the leading authorities on Orthoptera, for identification. He informed me that this form is not only a new species but also belongs to a new genus. Later, in the *Boletin de la Real Sociedad Española de Historia Natural*, p. 319, July 1910, he published his descriptions of the genus and species. As his paper, which was written in Spanish, appeared in a Spanish scientific journal not easily accessible to entomological workers in India, I published a note giving its main points, together with his original

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Latin descriptions in full, in the Journal of the Bombay Natural History Society, Vol. XX, No. 3, p. 879, 1911.

These are the only scientific communications that have, as yet, appeared. In addition to the above, extracts from a letter written by me containing some practical suggestions with regard to combating this pest, were published, by order of the Mysore Government, in the *Mysore Gazette*, Vol. 46, pp. 184 and 185 of 16th February 1911 and p. 200 of 23rd February 1911. These extracts were accompanied by photographs showing damage done by the pest as well as the results of combative measures. Mention of this pest is also made in the annual reports of the Agricultural Departments of Bombay and Madras for 1910.

Bolivar's original descriptions translated into English are as follows:—

*Colemania, gen. nov.*—Body elongate, subcylindrical, in the male strongly fusiform, arched in the middle. Head conical. Fastigium elongate with a distinct median furrow above, produced horizontally, anteriorly obtusely rounded, longer than the eye. Frons strongly reclinate, subsinuate in outline. Antennæ ———? with cylindrical base. Frontal costa sulcate throughout, somewhat compressed at the base, slightly depressed but quite distinct, becoming obsolete before the epistoma. Lateral carinæ of the frons sinuate, diverging somewhat anteriorly. Cheeks marked by a feeble but distinct granular line. Eyes small, little longer than broad, truncate posteriorly; ocelli not prominent, median ocellus between, basal ocelli in front of, the eyes. Pronotum conical, especially in males, in females almost cylindrical, with obtusely sinuate posterior border; sulci obsolete above; posterior transverse sulcus (sulcus typicus) traverses pronotum far behind the middle. Lateral lobes of pronotum elongate, margin entire, anterior margin oblique, inferior straight, posterior indistinctly sinuate, anterior angle obtuse, posterior approximately right. Elytra very narrow, linear, elongate, longer than the pronotum. Wings absent.

Prosternum provided with a very acute aciculate tubercle; mesosternal lobes elongate, truncate posteriorly, approximated in the male, in the female with space ampliated anteriorly; posterior angle rounded. Metasternal foveolæ in both male and female close together. Legs short, anterior femora in males incrassate, posterior femora slender; external median area narrow, with pinnate markings rather indistinct; geniculate lobe produced into an angle. Posterior tibiæ slender, in apical third somewhat ampliated and flattened above, armed internally with 11, externally with 9 spines. Posterior tarsi slender, first segment twice as long as the second. Abdomen cylindrical. Apex not at all clavate. Final segment in the male transverse, posteriorly trisinuate. Supra-anal lamina elongate, triangular, longer than the cerci, sulcate, acute, in female almost equilateral; cerci short, curved with almost subulate tip, in female minute and straight. Subgenital

lamina compressed, with a compressed carina posteriorly. Valves of the ovipositor short, sinuate.

*Colemania sphenarioides, sp. nov.*—Ground colour straw or yellow. Head behind the eyes with a broad purplish fascia and a yellowish band which extends from the antennæ to the anterior angle of the pronotum. Frons purplish. Vertex convex with a blue-black median line which is wider in front of the eyes. Antennæ with first segment pallid, the succeeding ones blue-black marked with a longitudinal pallid fascia beneath. Pronotum dorsally rufescent, latero-dorsally with a yellow fascia which is marked on the inner border with a black line; lateral lobes callous, punctate and marked with three fasciæ; superior fascia red, median fascia black, inferior fascia yellow; inferior margin slightly sinuate. Meso- and metanotum in males strongly incrassate, dorsum smooth, sides with a continuation of the prothoracic fasciæ; external fascia strongly punctate. Elytra towards the apex slightly ampliated, extending to the posterior border of the first abdominal segment, rufescent with paler veins. Legs pallid. Posterior tibiæ rufescent, armed with pallid spines which are black at the apex. Abdomen pallid dorsally, laterally with fuscous and grey patches. First segment provided with a tympanum.

Measurements of male :—

| | | |
|---|---|---|
| Body length ... ... ... | 39 | mm. |
| From eye to apex of head ... | 3 | ,, |
| Pronotum ... ... ... | 6·5 | ,, |
| Elytron ... ... ... | 8·5 | ,, |
| Posterior femur ... ... | 13 | ,, |

Measurements of female :—

| | | |
|---|---|---|
| Body length ... ... ... | 36 | ,, |
| From eye to apex of head ... | 2·8 | ,, |
| Pronotum ... ... ... | 6 | ,, |
| Elytron ... ... ... | 6·5 | ,, |
| Posterior femur ... ... | 12 | ,, |

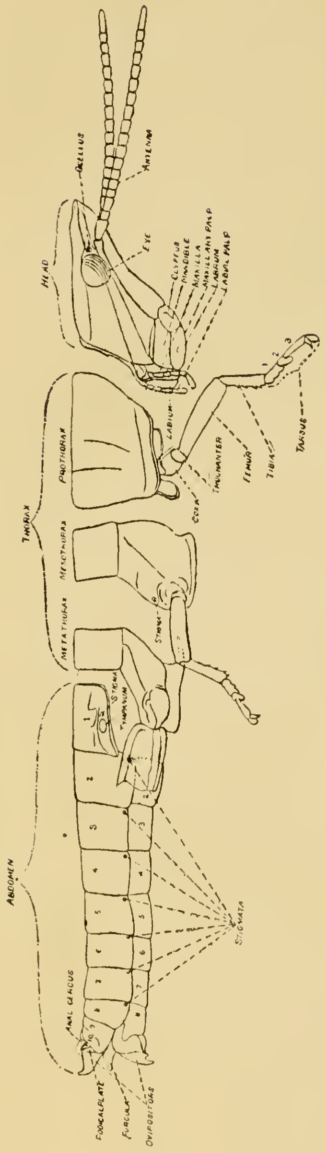
Locality, Honnali, 6-10-09.

Collectors, L. C. Coleman and K. Kunhi Kannan.

The above description is, in one or two respects, imperfect. The specimens were received by Prof. Bolivar somewhat damaged, with the result that the structure of the antennæ could not be made out. The antennæ differ somewhat in the two sexes. In both sexes, they have usually eighteen segments, but there is variation in this respect An examination of twenty females showed seventeen with eighteen segments and three with only seventeen segments. An examination of ten males revealed five with eighteen segments and five in which the third segment from the base showed a very distinct, though apparently not complete, division into two. This would give nineteen segments, but, as already stated, the division is not quite

complete. We must, thus, give the number of segments as varying from seventeen to nineteen.

The antennæ are thickest at about the third segment and taper from here gradually to the end. In the female, segments 3–8 have in section a triangular form which is particularly marked in segments 3–5. The more distal segments gradually change to a cylindrical shape. In the males, this triangular shape of the segments is usually not nearly so distinct, being marked usually only on segments 3 and 4. Plate X, Figs. 1 and 2 show these differences in structure. The antennæ of the female is marked on the lower angle with a narrow yellow band extending to the 8th segment. In the male this band is, at least usually, absent. Another feature which commonly varies slightly from the description given by Bolivar is the colour of the hind tibiæ. While some specimens have the hind tibiæ reddish throughout, in the majority of cases the basal half of the tibia is flavescent, only the apical half being reddish.[1]



TEXT-FIG. 1.

Outline of female of *Colemania sphenarioides*, *Bol.* dissected to show the various external features. The elytron or wing-cover is removed and only the base of the hind leg is shown.

Bolivar[2] places this form in his section *Orthacres*,

[1] Those unfamiliar with the external structure of a grasshopper should consult Text-fig. 1 in which are indicated the main external features.

[2] Bolivar, *Pyrgomorphinæ, Genera Insectorum Fasc.* 90, p. 44, 1909.

subfamily *Pyrgomorphinæ* and close to the genus *Orthacris* itself. Its chief distinguishing feature is the enlargement of the thoracic region especially in the males. While this fusiform shape of the body is much more marked in the male than in the female, still it is quite distinct in the latter also, especially if the specimen is viewed from above.

This insect is not at all difficult to recognise and is not likely to be mistaken for any other form occurring in the infested regions. Its most striking feature is the total absence of wings and the great reduction in size in the wing covers or elytra. Only one other insect has been found by me in the affected area that might be mistaken for it. This is a species of *Orthacris* which, of course, also lacks wings but is hardly more than half as large as *Colemania sphenarioides.* This form has been found in small numbers in grass lands and on grassy strips bordering fields in the neighbourhood of Honnali. It has, however, never been seen to attack crops of any kind. It has more than one brood or generation in a year and so is to be found in the adult state at various different seasons. It may be noted here that the nymphs of this form bear a decided resemblance to those of *Colemania sphenarioides* and might be mistaken for the latter.

## CHARACTER OF DAMAGE.

The chief damage caused by *Colemania sphenarioides* in Mysore is, as already stated, to jola. It, however, seems to attack all other dry land cereals cultivated in the neighbourhood, such as navane (*Setaria italica*), sajje (*Pennisetum typhoidium*), savé (*Panicum miliare*) and ragi (*Eleusine coracana*) with equal severity. Jola (*Andropogon sorghum*) however forms the staple cereal of the infested regions and the damage to it is much more marked.

Besides cereals, this form also attacks various pulse crops such as green gram (*Phaseolus mungo*), black gram (*Phaseolus mungo, var. radiatus*) and avare (*Dolichos lablab*) grown in the infested area. It also feeds upon pigeon pea or togari (*Cajanus indicus*) to a certain extent. In addition it can occasionally be found feeding on chillies (*Capsicum spp.*) eating both the leaves and the fruits. The damage

to all these crops is, however, much less severe than that to the cereals mentioned above. It appears likely that it may feed to a slight extent on cotton also, but the damage to this crop has, up to the present, been quite negligible. The insects can, of course, be found in considerable numbers on all these crops where they occur in infested areas and this leads the raiyats to suppose that the crops are being seriously injured. This applies especially to cotton, chillies and togari, all of which are present in the fields in considerable quantity at the time of jola harvest. A careful examination, however, shows that very little actual feeding is taking place, most of the insects simply copulating or resting on the plants. Avare, green gram, black gram and pigeon pea earlier in the season are more severely attacked.

The damage to the pulses consists in the eating of the leaves and flowers; in no case have any pods or seeds been found eaten by this grasshopper. On the other hand, in the case of all the cereals mentioned, not only are the leaves eaten but also the grains in the heads, the result being that in a severely attacked field practically nothing is left but the stalks or stems of the plants and the empty ears. Plate V, Fig. 1 shows a field of jola which has been almost completely destroyed in this way. All that is left of the leaves are the stiff and hard midribs which stand out like needles from the stalks. Plate III, Fig. 2 shows the effect produced upon a head of jola. In this particular case, almost every grain has been eaten. A few grains, lying more or less hidden by the outer branchlets of the head, have been left while one grain is half eaten and thus shows up strongly with its white eaten surface against the dark background. Plate III, Fig. 1 shows a healthy head for comparison. These two heads were photographed to about the same scale and a comparison of them reveals the fact that, in the case of the attacked plant, the growth of both head and stalk has been greatly stunted. This is, of course, due to the fact that the plant has been stripped of leaves and so has been unable to develop normally.

In the infested areas the soil is mainly of two types, *viz.*, the ordinary black cotton soil of the Deccan and red laterite soil. As a general rule the infestation on the black soil areas has been much more severe than that on

the red soil[1]. However, this contrast is in certain localities being obliterated and the infestation is gradually spreading out on to the red soil areas also. There seems no *a priori* reason why black soil areas should be worse infested, unless it is the fact that oviposition is decidedly more difficult in the red soil. This point will be touched on later. The possibility of the two types of soil producing plants which will be eaten by the grasshoppers with different degrees of avidity (a view commonly held by raiyats) cannot be entertained.

## LIFE HISTORY OF THE JOLA GRASSHOPPER.

The life history of the Jola Grasshopper is, in general, as follows:—The eggs hatch in July after the early monsoon rains have fallen. The young hoppers begin feeding upon the grass at the borders of the fields and upon the young crops, if they have already come up. Growth continues throughout July, August and September, the grasshoppers assuming the adult form late in October and November. Copulation takes place soon after the adult form is reached and shortly after this, egg-laying begins. This continues through November and into December, during which time the insects are particularly lethargic and very little feeding is done. By the end of December, most of the insects are dead, although a few may be found alive as late as January. The eggs remain in the soil till the following monsoon, when the young hoppers hatch and begin their work of destruction again.

Let us now examine more closely the individual stages of the life history.

*Egg-laying.*—As already stated, the worst infestation in the infected areas in Mysore is to be found in crops grown on black soil and it is here that the greatest number of egg-masses are laid. The grasshoppers seem to have no preference for particular parts of a field or for

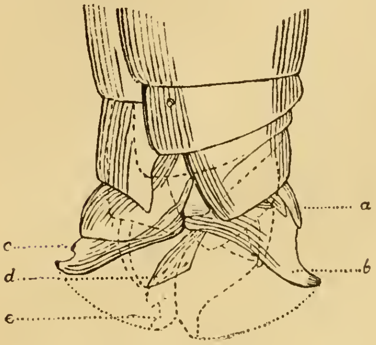
[1] This does not appear to hold universally. In a note prepared by Mr. Y. Ramachandra Rao, Assistant in Entomology, on this pest in Bellary District, and kindly furnished to me by Dr. C. A. Barber, Botanist to the Madras Government, the author states:—"The hopper is equally severe in both black and red soils, but, as far as observed, more harm is done in red soils, as here the eggs hatch out earlier." As already stated, this does not agree with observations made in Mysore. Information received from Mr. M. L. Kulkarni, Divisional Inspector of Agriculture, Bombay, indicates that in Dharwar District the infestation is worse on black than on red soil areas.

the grassy strips bordering them. Egg-laying, however, takes place most commonly in those places where the soil is most easily penetrated. The result is that, in the fields, the great majority of burrows are made in the bottoms or sides of the cracks which are so abundant in black soil at this time of the year. Through these cracks the grasshopper is able to get down into those portions of the soil which still retain a fair amount of moisture much more readily than they could by boring directly down through the top. Other favorite spots are the demarcation mounds which are freshly heaped up every year and on which numerous cracks develop. The egg-laying on grassy strips and patches seems, on the whole, to be much less general, for here the soil is very hard and the cracks are comparatively few in number. Not infrequently egg-laying takes place at the bases of the numerous bushes, especially tangadi (*Cassia auriculata*), found scattered over grassy areas. Here too, the female grasshopper can more easily burrow down into the soil.

On red soil areas, comparatively few cases of oviposition have been observed and these have been observed invariably at the bases of plants growing in the fields. Thus a number of females were observed burrowing at the bases of pigeon pea (*Cajanus indicus*) plants, the posterior end of the body being thrust down close to the base of the stem. The upper layers of the red soil are, at this time of the year, extremely hard so that boring would be a very difficult matter for such a comparatively feeble insect as this grasshopper. No cases of oviposition in red soil outside of those mentioned have as yet been observed.

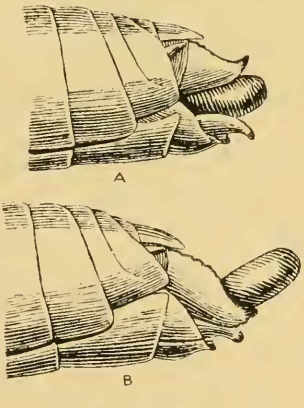
The process of burrowing is very similar to that occurring in the case of other grasshoppers. A striking feature is, however, the position which the grasshopper occupies during the process. The abdomen is thrust down in a slightly oblique to almost perpendicular direction. There is practically no bending of the abdomen, the whole body being kept almost in a straight line. In cases where the boring takes place in cracks of the soil, when the body is sunk to the full depth, it may lie almost completely in the crack below the surface of the soil, the antennæ alone projecting above the surface. The hind legs are drawn up so that the femora touch the body while, in turn, the tibiæ are closely approximated to them. The

bases of the hind femora are sunk into the burrow, while the middle pair of legs lie at its mouth; the front legs may touch the ground but more commonly they project freely into the air. Plate I, Fig. 4 and Plate VII, Fig. 1 show a female grasshopper sunk in the ground and in the act of laying eggs. In cases where burrows are made beside a plant stem, the insect commonly seizes the base of the stem with the front two pairs of legs and gradually backs downward as the burrowing progresses. The actual digging is done by the two horny pairs of ovipositors which are dug into the ground closed and then spread out, thus pushing the soil ahead of them. The posterior end of the body is able to rotate through 180° and so pressure can be brought to bear in all directions in the burrow, a cylindrical burrow being the result. Text-fig. 2 shows the boring mechanism. The dotted lines mark the position of the ovipositors when pushed closed into the soil, while the rest of the figure shows the ovipositors fully extended to thrust the particles of soil outward and upward. Text-fig. 3 shows the manner in which the egg is pushed out between the ovipositors.




TEXT-FIG. 2.

Ovipositors of Jola Grasshopper, showing action during digging; *a*, anal cercus; *b*, dorsal ovipositor; *c*, ventral ovipositor; *d*, furcula vulvalis; *e*, ovipositors closed.

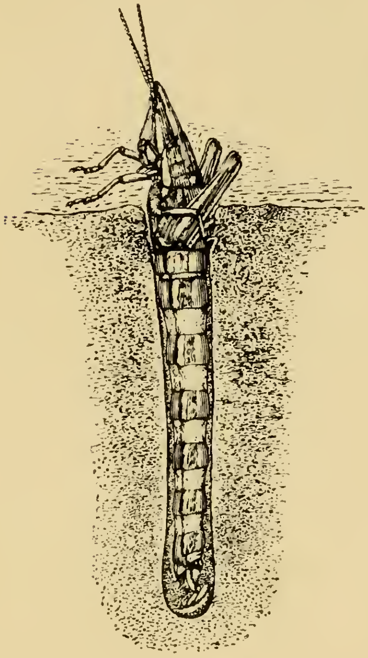



TEXT-FIG. 3.

Posterior end of female Jola Grasshopper showing exit of egg. A, first stage, in which egg lies between upper and lower pairs of ovipositors. B, second stage, in which egg is grasped between upper pair of ovipositors.

The whole process of burrowing and egg-laying has been studied carefully in the laboratory. The method

used in studying these processes has already been described for the Rice Grasshopper and is as follows:—An outer layer of soil, from one quarter to one-half inch in thickness, in a glass jar, is divided off from the rest by means of stout cardboard. The top of the soil is covered with the exception of this external layer. The grasshopper is thus compelled to burrow close to the glass. The process has already been described in considerable detail by me for the Rice Grasshopper and it is sufficient to say here that oviposition in the case of the Jola Grasshopper is almost exactly similar. The accompanying Text-fig. 4 gives an accurate picture of the grasshopper in the act of egg-laying. An egg has just appeared between the two pairs of ovipositors and the upper pair is moving down to seize the egg prior to depositing it. The great extension of the abdomen is worthy of notice, individual abdominal segments being extended to fully twice their original length. The time required for the digging of a hole and the deposition of an egg-mass is very considerable. In one case observed in the field, for the whole process in black cotton soil a period of one and a-half hours was taken from the beginning of digging to the completion of egg-laying and the emergence of the female from the ground again. The following periods were observed in rather light soil in the laboratory:—



TEXT-FIG. 4.
Female Jola Grasshopper laying eggs.

| | P.M. |
|---|---|
| Digging commenced ... ... | 4.40 |
| Egg-laying commenced ... ... | 5.42 |
| Do completed ... ... | 6.20 |
| Completion of deposition of froth on top of egg mass ... ... | 6.30 |
| Grasshopper emerged from hole ... | 6.34 |

## *EXPLANATION OF PLATE II.*

FIG. 1.—Part of an egg-mass of the Jola Grasshopper in a lump of black cotton soil.

FIG. 2.—Nymph of the first instar.

FIG. 3.—Nymph of the second instar.

FIG. 4.—Nymph of the third instar.

FIG. 5.—Nymph of the fourth instar.

FIG. 6.—Nymph of the fifth instar.

FIG. 7.—Adult male grasshopper.

FIG. 8.—Adult female grasshopper.

The hair-lines beneath the figures indicate the real lengths of the insects painted, the figures being somewhat enlarged.

Plate II.

We get here then the following figures:—

| | | Minutes. |
|---|---|---|
| Digging | ... ... ... | 62 |
| Egg-laying and deposition of froth | ... | 48 |
| Total | ... | 110 minutes or one hour and fifty minutes. |

Observations made in the field would indicate that this probably does not exceed the average length of time required there, the time recorded above for the case observed in black cotton soil being rather below the average.

The eggs are laid somewhat irregularly, there being little of that comparatively orderly arrangement noted in the masses of the Rice Grasshopper. The masses themselves are rather easily broken and the eggs are not at all firmly cemented together. However, the hole in the black cotton soil is a very solid one and under normal conditions there is little danger of the egg-masses coming to any harm. Plate II, Fig. 1 shows part of an egg-mass exposed in black cotton soil; above can be seen remains of the frothy or spongy mass which is deposited in the hole above the eggs. At times this spongy mass attains a length up to an inch, in some cases being longer than the egg-mass itself. Plate VII, Fig. 3 shows such a frothy plug in position above an egg-mass. Plate VII, Fig. 2 shows an intact egg-mass, from which the frothy covering has been removed on one side to reveal the eggs in their natural position.

The egg-masses vary considerably in size and in the number of eggs contained in them. They are much narrower than those of the Rice Grasshopper while at the same time they tend to be somewhat longer. Measurements of twenty-one masses gave dimensions varying from 23 mm. × 5·5 mm. to 13 mm. × 6 mm. Others have been found as short as 9 mm. and counts of eggs made on 21 masses gave the following results:—72, 61, 56, 55, 51, 49, 47, 43, 42, 41, 36, 36, 35, 35, 32, 30, 24, 23, 21, 9, 8. The average is 38 eggs per mass. Records indicate that a female Jola Grasshopper lays on an average two egg-masses so that we have about 75 eggs as the approximate number laid per female. Consistent with the position occupied by the female in egg-laying, the egg-masses are

placed approximately vertically and at a depth of one to two inches from the surface. In the field, this depth may be considerably increased where the grasshoppers sink themselves deep into cracks in the process of egg-laying. In this case a depth of three inches or more may be reached.

Egg-laying seems to take place in the field always late in the afternoon or in the evening. Most of the cases observed were noted just about sunset and more than once the coming on of darkness prevented the completion of observations. The earliest case of oviposition observed in the field was one on a demarcation mound about three o'clock in the afternoon. A search was also made in the early morning for ovipositing females but in no case were any found. In the insectary, where the insects were not exposed to direct sunlight, oviposition has been observed at almost all times of the day though here again more commonly in the afternoon.

*Development of the Jola Grasshopper.*—As already stated, the eggs remain in the ground throughout the winter months and hatch only after the early monsoon rains have fallen. In 1910, the egg-masses in field cages in the laboratory compound, Bangalore, hatched on the 22nd, 25th and 27th of July. In the field at Honnali, the hatching was first observed on the 29th of July. In 1910, the monsoon was late in beginning and it is probable that, in more normal years, the emergence may be somewhat earlier.

Here, as in the case of most grasshoppers, the shell splits open at the upper or head end and the insect extricates itself still covered by a thin membrane or amnion which is usually carried to the surface and shed there. This is by no means universal, however, as Plate VII, Fig. 5 shows. In this case the amnia have been left inside the shells, the young hoppers emerging as free insects from the egg. The two holes in the amnion, out of which the anterior pair of legs have been extricated, are visible in one of the figures. Plate VII, Fig. 4 shows a hopper in the act of hatching. The young hopper is, at first, pale but, within an hour or so, takes on the permanent dark colour to be described.

### FIRST INSTAR. (PLATE II, FIG. 2.)

| | |
|---|---|
| Length of nymph on day of hatching ... | 5·5—6·5 mm.[1] |
| Length of antennæ ... ... | 1·5 ,, |
| Number of segments to antennæ ... | 8 |

The structure of the antennæ (see Plate VIII, Fig. 8) is worthy of note. Segments 3-7 are subequal in length and triangular in section. Segment 2 is short, cylindrical. Segment 1 is almost triangular in outline. Segment 8 is very long, almost as long as the five preceding segments together.

The ground colour is greyish mottled with brown. A pale yellow band extends from the base of the antenna, beneath the eye across the cheek, along the ventral margin of the pronotum over meso- and metapleuræ on to the femur of the hind leg. A distinctly paler band runs along the dorsum from the anterior to the posterior end of the insect. The general shape is much as in the adult insect. There is, however, yet no sign of elytra and the thorax is not at all enlarged.

### SECOND INSTAR. (PLATE II, FIG. 3.)

| | |
|---|---|
| Length of body ... ... | 7— 7·5 mm. |
| Length of antennae ... ... | 2— 2·75 ,, |
| Number of segments to antennæ ... | 9—10 |

The new segments have been divided off from the base of the terminal club (see Plate VIII, Fig. 9). The divisions are usually still incomplete and may be absent entirely, in which case the antennæ have the same number of segments as in the first instar.

The general colour is somewhat paler than in the first instar, especially along the sides of the thorax and abdomen, so that the dorsal band is much less distinctly marked off. The depth of colour varies, however, so that it cannot be used as a distinguishing character. The chief distinguishing features are (*a*) increase in size of shaft of antennæ relative to terminal club, (*b*) the beginning of division in club, (*c*) the growth of the external sexual organs (*vide infra*).

### THIRD INSTAR. (PLATE II, FIG. 4.)

| | |
|---|---|
| Length of body ... ... | 12—14 mm. |
| Length of antennæ ... ... | 4— 4·5 ,, |
| Number of segments to antennæ ... | 10—12 |

The two basal divisions in the club have usually become distinct, while divisions have appeared in segments 6 and 7 and a further division may at times be noted in segment 3.

The terminal club, which in the first instar is about the same length as the five preceding segments combined, is now not much more than half their combined length.

The colour is, in many specimens, the same as that already

[1] One inch = 25 millimetres (mm.).

described for the second instar. In some cases, however, and this seems to be very common in the field, the nymphs in this instar assume a distinctly greenish colour (see Plate 1, Fig. 3) with a markedly reddish tint on the sides of the head, along the external surface of the posterior femur and at the end of the abdomen.

In this instar are to be made out the first indications of the development of elytra. In many cases there is a distinct downward and backward growth of the lower portion of the mesothoracic lobes while in other cases this growth is very indistinct. Scarely a sign of development of a wing bud on the metathoracic lobe can, as yet, be made out (see Plate VIII, Fig. 3).

### FOURTH INSTAR. (PLATE II, FIG. 5.)

| | |
|---|---|
| Length of body on day of moult | ... 16—18 mm. |
| Length of antennæ ... | ... 5·5—7 ,, |
| Number of segments to antennæ | ... 13—15 |

The colour variations are those noted for the third instar, the green variation, however, becoming more prominent.

In this instar, we have a splitting up of the insect into two groups as regards wing development. In some of the nymphs the lower borders of both meso- and metathoracic lobes become turned up. The turned-up portion of the mesothoracic lobe projects about half way back on the metathorax, while the metathoracic lobe laps over it so as partially to cover it (see Plate VIII, Fig. 5). It projects but slightly behind the posterior border of the metathorax. In other nymphs of this stage, the wing buds are in much the same condition as that described for the previous instar. The metathoracic lobe is, however, more distinctly developed and may show a slight projection at its posterior border (see Plate VIII, Fig. 4).

In my description of the Rice Grasshopper, I have recorded the occurrence of a similar phenomenon for that species except that it occurs there in the fifth and not in the fourth instar. In the case of the Rice Grasshopper, it was found that this difference was connected with differences in sex, practically all the males showing the advanced developmental stage. An examination of nymphs of the Deccan Grasshopper in the fourth instar does not, however, show this correspondence, as will be seen from the following rearing notes. In a rearing jar (No. 10), there were present, on the 10th September 1910, thirteen nymphs all in the fourth instar. Of these, eleven were males. The division as regards development of wing buds was as follows:—

A. Upturned wing buds, 7—all males.

B. Downturned wing buds, 6—4 males and 2 females.

A record from another jar (No. 8) taken on the 16th September showed, out of twelve nymphs (nine females and three males), only one with upturned wing buds and that a male.

From these, as well as from other breeding observations, it appears that about half the males undergo the more rapid development while other records indicate that the females split up in much the same way as the males.

FIFTH INSTAR. (PLATE II, FIG. 6.)

| | | |
|---|---|---|
| Length of body | ... | ... 22 —25·5 mm. |
| Length of antennæ | ... | ... 7·5—10 ,, |
| Number of segments in antennæ | | ... 15 —17 |

Colour variations as in previous instar.

Those nymphs which in the previous instar showed the more advanced development now show the elytral bud grown backward almost or quite to the posterior border of the metathorax (see Plate II, Fig. 6 and Plate VIII, Fig. 6). The metathoracic bud shows no appreciable change. Those nymphs which showed the more belated development now correspond in wing bud development to the more advanced group of the previous instar.

For those nymphs showing advanced development this is the last nymphal instar. With the following moult they assume the adult form.

SIXTH INSTAR.

| | | |
|---|---|---|
| Length of body ... | ... | ... 26·4—29 mm. |
| Length of antennæ | ... | ... 9·5 —11 ,, |
| Number of segments to antennæ | | ... 17 —18 |

Little need be added to the description for the fifth instar as the nymphs in the sixth instar only reproduce in general the structure noted for the more advanced forms in the previous instar, the only difference being the greater size.

From the above description, it will be seen that the Jola Grasshopper passes normally through either five or six instars. Apparently about half the grasshoppers undergo the more rapid development.

Specimens collected in the field show very great variation in size. The measurements published by Bolivar and myself were taken from comparatively large specimens. Males have since been collected in the field varying from 23 mm. to 40 mm. in length while females have been found varying from 25 mm. to 40 mm. The females are much stouter than the males and on the average decidedly longer. Reared specimens have not attained the extreme size of those captured, the males varying from 26 mm. to 34 mm. and the females from 30 mm. to 34 mm. It is very probable that the conditions in confinement were not favourable for growth. The small specimens taken in the field were found in one or two localities only, and it appears likely that here also the food supply was insufficient or other conditions were not so

favourable. In any case, where such a marked variation in size exists, it is clear that the measurements given above for the various nymphal instars are only approximate and cannot be used in distinguishing one instar from another. For this purpose, the structure of the antennæ, the development of wing buds, changes in colour and the development of the posterior end of the abdomen will furnish the necessary information, and with a little practice one is able to identify the instar of a particular nymph with a fair degree of accuracy.

The table on page 17 gives the results of three separate rearings, and these records may be taken as typical.

From this we get the following periods for the various instars:—

| | | |
|---|---|---|
| Rearing A :—1st instar | 13—19 | days |
| 2nd ,, | 15—14 | ,, |
| 3rd ,, | 12—17 | ,, |
| 4th ,, | 14—19 | ,, |
| 5th ,, | 17—19 | ,, |
| 6th ,, | 18—26 | ,, |
| Total length of development for individuals with 5 instars | 86—87 | ,, |
| Total length of development for individuals with 6 instars | 89-112 | ,, |
| Rearing B :—1st instar | 12—13 | ,, |
| 2nd ,, | 14—17 | ,, |
| 3rd ,, | 14—18 | ,, |
| 4th ,, | 13—16 | ,, |
| 5th ,, | 14—19 | ,, |
| 6th ,, | 18—19 | ,, |
| Total length of development for individuals with 5 instars | 81—84 | ,, |
| Total length of development for individuals with 6 instars | 85—89 | ,, |
| Rearing C :—1st instar | 13—14 | ,, |
| 2nd ,, | 11—13 | ,, |
| 3rd ,, | 12—14 | ,, |
| 4th ,, | 13—17 | ,, |
| 5th ,, | 13—14 | ,, |
| 6th ,, | 17—24 | ,, |
| Total length of development for individual with 5 instars | 68 | ,, |
| Total length of development for individuals with 6 instars | 79—88 | ,, |

The nymphal instars are thus approximately two to two and a-half weeks in length. The sixth instar is somewhat longer than the rest or from two and a-half to three

# TABLE OF REARINGS OF JOLA GRASSHOPPER.

| Hatched | | 1st Moult | | | 2nd Moult | | | 3rd Moult | | | 4th Moult | | | 5th Moult | | | 6th Moult | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | No. | Date | No. | Total | Date | No. | Total | Date | No. | Total | Date | No. | Total | Date | No. | Total | Date | No. | Total |
| 6 8 10 | 10 | 19 8 10 | 2 | | 3 9 10 | 1 | | 15 9 10 | 1 | | 29 9 10 | 1 | | 16 10 10 | 1 | | 3 11 10[1] | 1 | |
| 1 died on 14 8 10 | | 20 8 10 | 1 | | 4 9 10 | 3 | | 17 9 10 | 2 | | 2 10 10 | 2 | | 21 10 10 | 2 | | 11 11 10[1] | 1 | |
| | | 23 8 10 | 4 | | 5 9 10 | 2 | | 19 9 10 | 1 | | 6 10 10 | 2 | | 30 10 10 | 1 | | 13 11 10[1] | 1 | |
| | | 24 8 10 | 1 | | 8 9 10 | 2 | | 20 9 10 | 1 | | 12 10 10 | 1 | | 31 10 10[1] | 1 | | 23 11 10[2] | 1 | |
| | | 25 8 10 | 1 | 9 | Unrecorded | 1 | 9 | 21 9 10 | 1 | | 13 10 10 | 2 | | 1 11 10[1] | 1 | | 26 11 10[1] | 1 | 5 |
| | | | | | | | | 22 9 10 | 1 | | 14 10 10 | 1 | 9 | 2 11 10 | 1 | 7 | [1] Female adults | | |
| | | | | | | | | 24 9 10 | 1 | | Two escaped during this instar | | | [1] Adult males | | | [2] Male adult | | |
| | | | | | | | | 25 9 10 | 1 | 9 | | | | | | | | | |
| 10 8 10 | 3 | 22 8 10 | 1 | | 5 9 10 | 1 | | 19 9 10 | 2 | | 2 10 10 | 1 | | 16 10 10 | 1 | | 3 11 10 | 1 | |
| 11 8 10 | 2 | 24 8 10 | 4 | 5 | 6 9 10 | 1 | | 24 9 10 | 1 | | 4 10 10 | 1 | | 19 10 10 | 1 | | 7 11 10 | 1 | 2 |
| | | 1 died on 24 8 10 | | | 8 9 10 | 1 | | 28 9 10 | 1 | 4 | 13 10 10 | 1 | | 30 10 10[1] | 1 | | Both adult males | | |
| | | | | | 10 9 10 | 1 | 4 | | | | 14 10 10 | 1 | 4 | 2 11 10[1] | 1 | 4 | | | |
| | | | | | | | | | | | | | | [1] Adult females | | | | | |
| 9 8 10 | 6 | 22 8 10 | 3 | | 2 9 10 | 1 | | 14 9 10 | 1 | | 27 9 10 | 1 | | 10 10 10 | 1 | | 27 10 10[1] | 1 | |
| | | 23 8 10 | 2 | 5 | 3 9 10 | 1 | | 16 9 10 | 1 | | 30 9 10 | 1 | | 12 10 10 | 1 | | 5 11 10[2] | 1 | 2 |
| | | | | | 5 9 10 | 3 | 5 | 17 9 10 | 1 | | 2 10 10 | 1 | | 16 10 10[1] | 1 | 3 | [1] Male adult | | |
| | | | | | | | | 19 9 10 | 1 | 4 | 6 10 10 | 1 | 4 | [1] Male adult | | | [2] Female adult | | |

and a-half weeks. The total length of development is about two and a-half to three and a-half months. This agrees with our records from the field where emergence took place during late July and August and where adult grasshoppers were found in the latter part of October and in November. In a few exceptional cases, nymphs of the last instar were found in the field as late as the middle of December.

A general description of the adult insect has already been given, but a few points remain to be mentioned. While the posterior wing bud is quite distinct in the last two or three nymphal stages, we find that, in the adult, practically all trace of it disappears. Associated with the loss of the powers of flight, is a weak development of the organs of locomotion generally. The legs are short and slender and the shortness and slightness of the hind femora as compared with the abdomen are very marked. An examination of the musculature shows a very feeble development compared with that in a fairly normal form, such as the Rice Grasshopper. Associated with the abortion of the wings, is the absence of more than mere traces of the wing musculature. This weakness in powers of movement is, however, not at all associated with a weakness in constitutional powers, the Jola Grasshopper being in this respect decidedly robust.

Another feature worthy of note is the presence of a glandular structure, whose duct opens in the medio-dorsal line on the articular membrane between the first and the second abdominal segments. The gland itself is shown in Plate X, Figs. 3 and 4; its opening in Plate X, Fig. 5. As indicated, it is a paired structure closely applied to the dorsal body wall in the region of the first abdominal segment. The secretion is a slightly yellowish fluid somewhat milky in appearance with a peculiar odor and having a distinctly alkaline reaction. It appears to be repugnatorial in nature. The secretion is capable of being ejected with considerable force, being squirted at times to a distance of one or two inches. Similar glands have been found in some other members of the sub-family *Pyrgomorphinæ*, *e.g.*, in *Pœcilocerus pictus*, Fabr., and *Attractomorpha crenulata*, Fabr.

In the above description, an account of the development of the posterior end of the body has not been

included. This development is illustrated in Plate IX, the development in the male being shown on the right side and that of the female on the left. The development corresponds quite closely with that already described for the Rice Grasshopper, so there is no occasion to go into details here. As indicated (Plate IX, Figs. 1-6), the ovipositors develop as paired outgrowths on the lower or ventral side from the posterior border of the eighth and the ninth abdominal segment respectively. These processes gradually grow backward and gain in stoutness until, in the adult stage, they form two powerful pairs of diggers. Here, as in the case of the Rice Grasshopper, we find the separation of two lobes from the inner faces of the two upper processes (see Plate IX, Fig. 3) to form a forked structure (*furcula supravulvalis*) which comes to lie just above the genital opening.

In the male, a single process grows back gradually to form the scoop-shaped structure (subgenital lamina) in which the penis comes to lie (see Plate IX, Figs. 7-12).

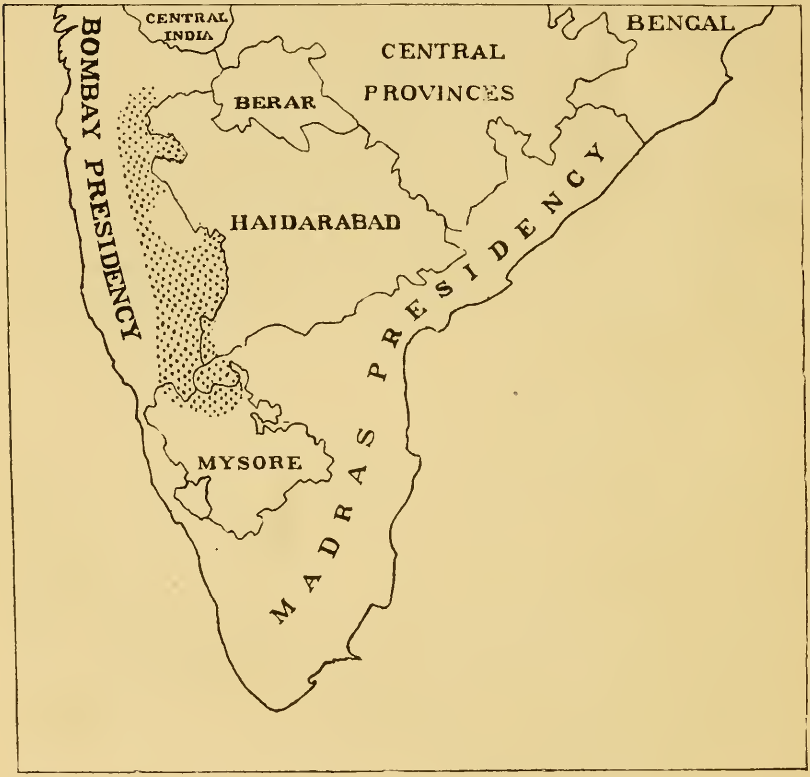
## DISTRIBUTION OF THE JOLA GRASSHOPPER.

The Jola Grasshopper has by far its most extensive distribution in the Bombay Presidency, where it is to be found in almost all the Deccan Districts including a small part of Khandesh. It has not yet appeared in Sholapur District. In addition, it is to be found in almost all the taluks of the Karnatic Districts, Belgaum, Bijapur and Dharwar. In Madras Presidency, it has appeared only in Bellary District, in Adoni, Alur, Kudligi, Hadagalli and Harpanhalli Taluks.[1] In Mysore it is, at present, restricted to the northern parts of Chitaldrug and Shimoga Districts near the point where Mysore State and Bombay and Madras Presidencies meet. The taluks affected are:—Honnali and Channagiri in Shimoga District; Davangere, Jagalur and Chitaldrug in Chitaldrug District. In all probability it extends, at least to some extent, into Hyderabad as it has been found in districts bordering on that State. Enquiries made by me have, however, elicited the fact that

[1] The information with regard to the distribution of the grasshopper in Bombay Presidency was kindly furnished by Mr. G. F. Keatinge, Director of Agriculture, Mr. T. F. Main, Deputy Director of Agriculture, and Mr. M. L. Kulkarni, Divisional Inspector of Agriculture. The information for Madras Presidency was furnished by Mr. Y. Ramachandra Rao, Assistant Entomologist, through Dr. Barber.

it has not been reported to the Hyderabad authorities as yet. The approximate area over which the Jola Grasshopper is known to occur is indicated on the accompanying map (Text-fig. 5).

Considering its present distribution, it is practically certain that this pest has originated in Bombay Presidency and has spread from there into Madras and Mysore. Just when and where it made its first appearance as a pest is

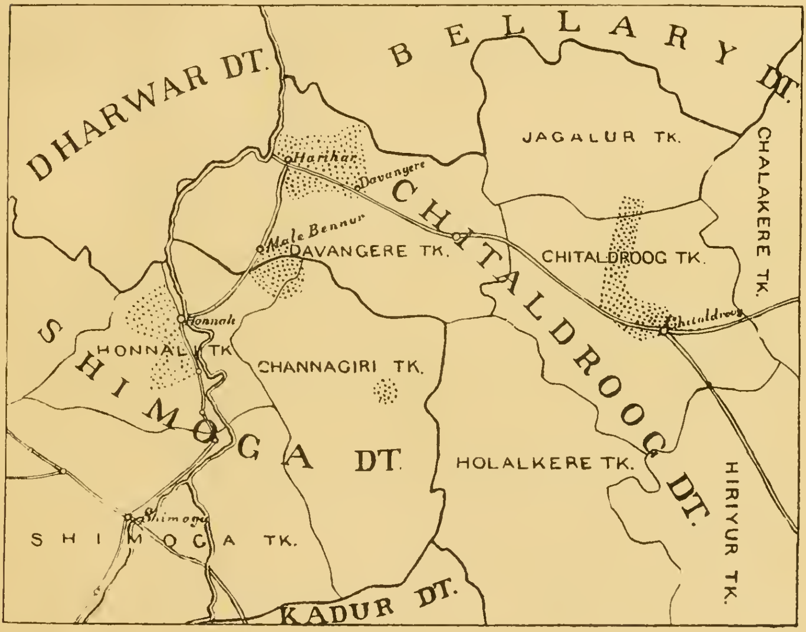



TEXT-FIG. 5.

Map of South India to show approximately the area infested by the Jola or Deccan Grasshopper.

unknown. Mr. T. F. Main, Deputy Director of Agriculture, Bombay Presidency, is of the opinion that it has been present there for many years, though it has excited attention only within the last four or five years. It has been present in Mysore as a pest for only about four or five years and the same appears to be the case in the Madras Presidency. It is clearly a form indigenous to the Deccan and

probably was originally a harmless feeder on grass. Grasshoppers belonging to the section *Orthacres* are by no means common forms in India and, where found, appear usually to occur in small numbers. This is the first one of the family that has appeared as a pest. We have here, in all probability, an interesting example of a harmless insect becoming a serious pest by modifying its feeding habits. With the more abundant and nutritious food provided by the cultivated cereals, it has increased very rapidly in numbers, so that it may now be looked upon as one of the most serious grasshopper pests in India.




TEXT-FIG. 6.

Map of portions of Shimoga and Chitaldrug Districts to show areas infested by the Jola Grasshopper.

It must not be supposed that this pest is to be found evenly distributed over the districts and taluks enumerated above. In fact, the distribution appears to be decidedly localized. The accompanying map (Text-fig. 6) shows in greater detail the distribution in Mysore. As indicated, there are five infested areas quite distinct and separate from each other. As will be noticed, all of these, with the exception of the area in Channagiri Taluk, are situated on

main roads where the traffic is heavy. A similar localized distribution occurs in Bellary District and the same is the case with regard to those portions of Dharwar District bordering on Mysore. The reason for this localization is not clear but a possible explanation is given below.

The fact that this pest has been doing damage for only a comparatively short time prevents us from expecting that this localization will persist. In fact, we may, with a fair degree of certainty, predict that the insect will spread from these various centres, so that in comparatively few years it will cover those taluks already infested and will gradually spread out from them to the neighbouring ones, so that the whole of the northern part of the State where dry land cereals are extensively grown is in danger of infestation within a comparatively short time.

## CAUSES FOR UNEQUAL DISTRIBUTION OF THE GRASSHOPPERS.

An examination of the map marking the distribution of the Jola Grasshopper in Mysore reveals, as already stated, the fact that this pest is not present over one continuous area but that it is to be found in more or less isolated tracts varying from one to several thousand acres. These tracts are, at times, considerable distances apart, so the question at once arises how the pest has spread from one to the other. That the pest has been present feeding on wild plants in all the localities now infested and that in all these centres it has gone over from wild plants to feed on cultivated crops, is highly improbable. The fact that the infested areas have been enlarging from year to year, in itself, indicates that this grasshopper, although wingless, has considerable powers of spreading. However, such a gradual spread cannot account for its appearance in distinctly separated tracts. The fact has, however, been observed in connection with the extensive cart traffic which takes place between places in Dharwar District and those in Shimoga or Chitaldrug District, that jola is usually cut and taken along as fodder in the carts.[1] It might very well happen, then, that a cart going from an infested tract would take along with the

[1] This fact was first brought to my attention, by B. C. Shantappa, Fieldman in my office.

jola a certain number of the grasshoppers, for these insects are sluggish in the extreme and might, in all probability, be carried many miles in a cart without becoming in the least disturbed.

This probably happens comparatively rarely, otherwise the spread of the pest would have been much more rapid and general than it has been. It may frequently happen that the number so transported is too small for the grasshoppers to make a start in the new territory, for they might all be destroyed by various natural enemies or die from other causes before they reach maturity and are able to lay eggs. In any case, this possible means of spread is a matter of considerable importance, and the knowledge of its possibility should be widely spread, so that precautions may be taken to guard against it as far as possible in the future.

With regard to the gradual spread within the territories already infested, some important observations have been made. It has already been noted that, up to the present, crops grown on black cotton soil have suffered most; at least that is the case in Mysore. A possible reason for this has already been suggested. During the summer of 1910 there was, however, a marked tendency in some localities for the grasshopper to spread in numbers on to the red soil tracts, and it is probably only a question of a year or so when these will be almost as badly infested as the black soil tracts.

Streams are among the most efficient checks to the spread of the pest. A good example of this was found in the infested villages, Marikoppa, Hattur, Dodyarehalli and Madenhalli, west of Honnali, just north of the Honnali-Shikarpur road. The infested lands of these villages lie between two streams which run almost parallel to each other and empty into the Tungabhadra just below (north of) Honnali. The worst affected portion is the strip of black cotton soil which lies midway between the two streams. From the middle, this soil shades off on either side towards the streams into a red, more or less sandy loam where the pest was not so serious but was nevertheless present. The two banks of the more southerly stream were followed and examined for a distance of between two and three miles and it was found that, on the northern bank, the grasshoppers could be found in

numbers on grass right down to the water's edge. On the southern bank, on the other hand, for the first mile and a half, not more than half a dozen grasshoppers could be found, and it was only in one place, and this near where a cart-track crossed the stream, that they could be found in greater abundance. This stream was, at the time of examination (7th, December 1910), not more than nine feet wide, and yet it had formed a quite effectual check to the grasshoppers. They are, however, very slowly gaining a foothold on the southern side of the stream and in the course of two or three years it will probably be as badly infested as the land on the northern side.

Larger streams or rivers would, undoubtedly, form a practically impassable barrier to the spread of the grasshopper, were it not for the traffic by means of ferries and bridges that is continually going on between the two sides. Thus at Honnali the land in the village of Devanayakanahalli, on the southern side of the Tungabhadra, is badly infested while, on the opposite side in the neighbourhood of the ferry landing, the pest has made its appearance in small numbers. It is, of course, impossible to stop the traffic, but an attempt should be made to rouse the raiyats and cartmen who, by the way, for the most part have lands themselves, to the importance of seeing that their carts do not carry any of these grasshoppers where they move from an infested area to one not yet infested. The difficulty is, of course, to create any semblance of public spirit, the ordinary raiyat saying, "If my crops are attacked, I fail to see why I should endeavour to prevent the spread of the pest on to the land of others."

## EFFECT OF WEATHER UPON THE GRASSHOPPER AND UPON THE EGGS.

From observations made during the last two years, it appears that this grasshopper is not at all sensitive to changes of weather. The summer of 1910 was abnormally wet and yet the pest was more serious than it had ever been before. There was no sign of any disease, fungus or otherwise, among the hoppers, something which commonly occurs among insects during abnormally wet seasons. The egg-masses also do not appear to be sensitive to

exposure to air or moisture, provided they are kept intact. If, however, egg-masses are broken, so that the individual eggs are exposed to the air and sun, they quickly collapse. This, together with the fact that the egg-masses are easily broken, gives us a hint as to a possible means of successfully combating the pest.

## NATURAL ENEMIES OF THE JOLA GRASSHOPPER.

Among the higher animals, the most important enemy of the Jola Grasshopper appears to be the common pariah kite (*Milvus govinda*, Sykes). This bird has been observed feeding on the grasshoppers and the number it disposes of must be decidedly large. Unfortunately, the birds themselves are not very numerous in the localities where the grasshoppers occur, so it is hardly likely that they could make a real impression on the huge numbers of the grasshopper to be found in badly infested regions. Plate VII, Fig. 9 shows a vomited mass, cast out by one of these birds, collected under trees close to the Honnali Travellers' Bungalow, where the birds came to perch at various times during the day and night. Such a mass consists, almost exclusively, of pieces of the indigestible skeletons of these grasshoppers. These birds were frequently observed feeding on the grasshoppers in the field, and the stomach of specimens collected revealed the presence of the insects in large numbers. Another bird observed feeding on the grasshopper is the smaller white scavenger vulture (*Neophron ginginianus*, Lath.). Other birds reported by a very intelligent raiyat as eating this insect are, the southern grackle (*Eulabes religiosa*, Linn.) and the cattle egret (*Bubulcus coromandus*, Bodd.). Another probable enemy is the common myna (*Acridotheres tristis*, Linn.), which is known to feed extensively on grasshoppers.

Among the lizards found in the fields where the grasshoppers are prevalent, one species (*Sitana ponticeriana*, Cuv.) seems to feed upon the exposed eggs to a certain extent. It has been found that, wherever egg-masses have been exposed and broken in the fields, the great majority of the eggs have disappeared and it is probable that they have, for the most part, been eaten by this

form. In captivity, they were found to feed upon the eggs. They could become of real importance in keeping the pest in check only if egg-masses were exposed in large numbers, something which does not happen under the ordinary methods of cultivation.

Of insects preying upon the Jola Grasshopper, only two[1] have been discovered up to the present. One of these is an unidentified robber fly (Fam. *Asilidæ*) which was found capturing the grasshopper nymphs at Honnali in August (see Plate VII, Fig. 8). The other form is a more important and interesting species. Only its larval form has as yet been discovered. It is one of the blister beetles (Fam. *Cantharidæ*) but which one it is impossible to say until adults have been reared. The larva has been found in the egg-masses feeding upon the eggs and from the size of the larvæ already collected and the work they have done it seems possible that a single larva can destroy a number of egg-masses. The first specimens of these beetles received in this office actually feeding on the eggs were furnished by Mr. Y. Ramachandra Rao, Assistant Entomologist, Madras Agricultural Department, from material collected by him in Bellary District in February 1911. Plate VII, Fig. 6 shows one of these larvæ with its head buried in an egg-mass, the eggs of which it has almost completely devoured, while Fig. 7 on the same plate shows the larva removed from the egg-mass. Since then, this insect has been collected at Harlahalli near Malebennur, Shimoga District (on 26th and 27th March 1911) and later near Honnali. Previously, in June 1910, what is probably the coarctate or resting stage of the same larva was found in considerable numbers during ploughing operations in the neighbourhood of Honnali.

This is, as far as I am aware, the first instance in India where blister beetle larvæ have been found feeding on the eggs of grasshoppers in the field. In addition, the resting (coarctate) larval stage of a blister beetle (probably *Mylabris sp.*) has been found near egg-masses of the Rice Grasshopper in the field and the larvæ of the common blister beetle *Mylabris pustulata*, have been reared to the third instar on grasshopper eggs in the insectary here.

[1] In addition, one or two specimens of a small parasitic wasp have been found in eggs of the Jola Grasshopper.

## MEANS OF COMBATING THE JOLA GRASSHOPPER.

*Indirect combative measures.*—The fact that, up to the present, the Jola Grasshopper has not attacked certain crops, such as cotton, chillies and gingelly, to any appreciable extent, would suggest the possibility of combating the pest indirectly by growing these crops for a number of years in the infested tracts to the exclusion of the crops that are attacked and in this way starving out the grasshopper. As a matter of fact, a number of the raiyats cultivating lands in the infested area have expressed their intention of going in largely for the cultivation of cotton and chillies this year.

That this method could not be applied thoroughly enough to get rid of the pest, is fairly certain, while it would tend to increase rather than to decrease the danger of spread. While cotton is at present a very profitable crop and an increase in its acreage would be beneficial, it must not be forgotten that jola forms the staple article of food for both man and beast in this region, and anything which would seriously and permanently decrease its acreage might lead to disastrous results during years of scarcity. On the other hand, there is always the decided danger that, as soon as the more favoured articles of diet are removed, this grasshopper will cultivate a liking for those crops which it now leaves untouched. The fact that it has appeared as a pest only within the last seven or eight years, indicates that it is at present in a decidedly adaptable stage in its evolution and the alternative between feeding on plants at first somewhat distasteful, or starving, might lead to the necessary change in feeding habits, in which case, instead of bringing about the control of the pest, we should simply have increased its destructiveness.

*Direct combative measures.*—These may be directed against this grasshopper either in the egg or in the nymphal stage. Any measure directed against the adult stage would be comparatively useless, even if possible to apply, for by that time the insect has practically completed its destructive work. Practical measures that could be applied towards the destruction of the eggs would be most suitable, as we should thus be able to destroy the insect

before it had been allowed to do any damage whatever. Such measures are, however, attended by difficulties from the fact that the eggs are deposited in the ground. Searching for and collecting egg-masses is, therefore, practically out of the question.

The fact that the egg-masses are, to a large extent, deposited in the fields themselves indicates that measures for (*a*) exposing the eggs to the air, or (*b*) burying the masses deeper in the soil, might be successful.

In order to expose and break up the egg-masses, a shallow ploughing about three or four inches deep with an improved plough which would invert the soil, followed by a thorough breaking of the clods, would be required. By this means, the egg-masses would be largely brought to the surface and would be broken up so as to be exposed to the action of sun and air and to destruction by lizards and other animals which feed upon them. Such a procedure would, however, be attended by very considerable difficulties, especially on black cotton soil where the eggs are most abundantly deposited. Such a shallow ploughing would have to cut into the very stiff soil just beneath the surface layer, which is kept in a more or less powdery state by frequent cultivation with the bullock hoe (Kunte), and this would be practically impossible unless the soil contained just the proper degree of moisture, something which cannot be counted on. It has not, as yet, been experimented upon in Mysore for this reason.

A deep ploughing of from eight to nine inches, accompanied by an inversion of the soil, would, on the other hand, bury large numbers of the egg-masses much deeper in the soil than they are normally. If this were followed by a fair amount of rain, the lower layers of the inverted soil would run together, with the result that the grasshoppers on hatching would have to work their way through some five or six inches of soil to emerge, instead of the two inches of soil which normally lie above them. Whether this method would be successful would depend largely upon two factors, (*a*) whether the clods were properly inverted and were packed down properly afterwards and (*b*) whether the young hoppers were sufficiently strong to make their way up through the additional depth of soil. Actual ploughing experiments with an improved plough, used by the Agricultural Department in the spring of 1910, showed that the

first condition can be obtained. To get data with regard to the burrowing powers of freshly-hatched nymphs, experiments were carried out in the insectary and these have shown that the newly-hatched nymphs are particularly weak.

Five glass test tubes were filled with black cotton soil; in two of them (*a*) egg-masses of the Jola Grasshopper were buried at a depth of five inches, in the other three (*b*) at a depth of six inches. The soil was lightly pressed down above these masses so as to reproduce conditions that would occur in the field as closely as possible. It retained a good physical texture with ample air spaces.

The eggs were buried on the 9th August 1910, and the nymphs hatched on the 6th to the 9th of September. On the 14th September the tubes were examined with the following results:—

Tube *a* 1—Nymphs all dead; one has worked its way up two and a-half inches. The rest have come up only about one inch.

Tube *a* 2—Nymphs all dead; none has come up more than one inch.

Tube *b* 1—Nymphs all dead; none has come up more than one inch.

Tube *b* 2—Nymphs all dead; a few have worked their way up two and a-half inches; the others are scattered between these and the bottom of the tube.

Tube *b* 3—Nymphs all dead; some have got up one and three-quarters inches, the rest are scattered between them and the bottom of the tube.

In the case of the last tube, the egg-mass was removed practically intact. It had been inserted upside down and the nymphs had apparently all emerged through the lower (the morphologically upper) end of the mass.

The experiment on deep ploughing, carried out in a badly-infested tract near Honnali, was not on a sufficiently large scale to give definite results. In order to obtain accurate results, it would be necessary to deep-plough the whole of the infested area in a village, otherwise the effect of the deep ploughing would be obscured by the migration of the grasshoppers from the untreated on to the treated portions. On account of the apathy and, at times, the active opposition of the raiyats, only about sixteen acres could be ploughed. As careful an observation of the emergence

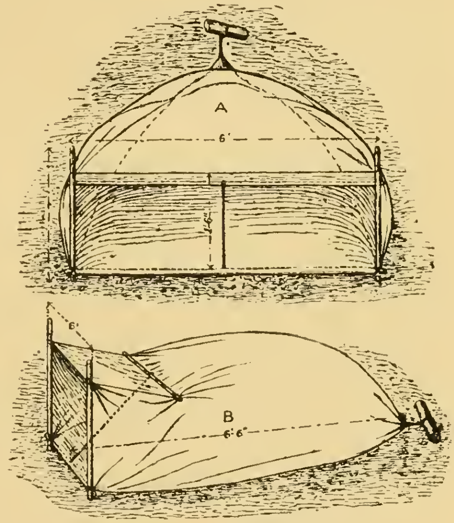
as possible was kept and there is no doubt that the emergence was reduced greatly on this portion. However, as already indicated, this difference was soon more or less equalized by the migration of grasshoppers from the surrounding plots.

This is hardly the place to discuss the other beneficial effects of deep ploughing, but it may be mentioned in passing that the work of weeding was very greatly reduced. No weeding was necessary on this deeply-ploughed land, whereas on the surrounding plots three or four weedings were required. The improvement in the growth of the crop on the deeply-ploughed portion was very noticeable.

The use of the country plough for destroying the eggs of the Jola Grasshopper is hardly likely to yield the best results. Two types of country ploughs are in use, the one small and stirring only the upper three or four inches of soil and the other large going to a depth of about six inches. The difficulty with both is that only a part of the soil is actually stirred by the plough, the portions lying between two furrows being left untouched. Furthermore the clods in which the egg-masses are buried are left pretty much in their normal position. If work with these ploughs should be accompanied by a thorough breaking up of the clods and should be done early enough, considerable good might be done. But this means the expenditure of a great deal of labour. Neither of these ploughs has any inverting power, so that they cannot be used to bury the egg-masses deeper in the soil, even were they capable of going sufficiently deep for the purpose.

With regard to destroying the Jola Grasshopper in its developmental stages, it may be stated, first of all, that all thought of using a poison spray or a poison bait to kill the hoppers must be abandoned. The expense of such treatment would be practically prohibitive where the hoppers are present over such large areas and on crops which are not particularly profitable. On the other hand, the danger of poisoning cattle, sheep and goats has to be taken into account. The results of experiments conducted in connection with an investigation of the Rice Grasshopper indicated that the carrying out of a similar series of experiments on the Jola Grasshopper would, in all probability, be a waste of time and money, so no such experiments were conducted.

There remained, then, only the catching of the nymphs by means of some suitable appliance. For the purpose, bags of the general pattern used in experiments on the Rice Grasshopper were employed. Certain alterations were found necessary to make the bags suitable for work in jola. The stalks of this crop are comparatively stiff and unyielding, so a long pole of bamboo or split areca stem was tied along the lower edge of the bag mouth to give it the required rigidity. In order to prevent the bag "ballooning" too much when it was being drawn rapidly against the wind, a heavy piece of wood was tied to the pointed closed end of the bag, while a pole of bamboo or split areca stem was tied across the top of the bag about one and a-half feet back from the mouth, a string being passed from the centre of this pole through a hole made in the top of the bag and down to the middle of the pole on the lower edge end of the bag mouth (see Text-fig. 7). By lengthening or shortening this string, the proper-sized opening of the bag can be obtained. Bags thus made, about four to six feet wide and one and a-half to two feet high at the mouth and about six feet deep, were found to answer exceptionally well (see Plate IV, Fig. 1 and Text-fig. 7). They could be readily drawn by two men on the run through the crop while the catches obtained were very satisfactory.




TEXT-FIG. 7.

Bag used in catching Jola Grasshoppers. A. Front view. B. Side view.

A point essential to the success of bagging on jola itself is that it should not be left too late. When the jola has reached a height of three feet, it is practically impossible to bag effectively. The stalks have become so unyielding that they will not bend before the bags, the result being that the bag cannot be dragged as close to the ground

as is necessary for good work. The best results can be obtained when the jola is not more than a foot or a foot and half high, so bagging should be begun almost immediately after the general emergence of the pest. Delay means an increase in the amount of damage done, more vigorous insects, which are therefore less easily caught, and greater difficulty in bagging on account of the height of the crop. Plate IV, Fig. 1 shows two bags being used in a jola field where the crop is about two feet high and where bagging was done quite effectively.

Another point that must be emphasized is the necessity of dragging the bag rapidly. It should, in fact, be dragged through the crop on the run. It is only in this way that the most satisfactory results can be obtained. It is moderately hard work but, with a bag of the size given above, it can be done without trouble by two men. As far as possible, bagging should be done against the wind, not with it. The insects are much more readily caught if this practice is followed.

During the first few weeks after the emergence of the pest in 1910, the grasshoppers confined themselves quite largely to grassy strips bordering the fields. This was due partly to the fact that the crops which were sown very late, were not yet up when the grasshoppers emerged. From these grassy strips, they gradually worked out into the fields. It was, therefore, at first found necessary to bag only on these grassy patches and strips and on the outer ten or fifteen feet of the crop. It is possible that the early distribution of the pest in 1910 was somewhat abnormal owing to the late sowing of the jola. If this is not the case, the bagging work will remain comparatively simple and easy. On the other hand, if with a more normal season the grasshoppers become more rapidly distributed over the whole crop, the work of bagging will, of course, be increased.

It is only on jola and sajje that difficulties are experienced in bagging after the crop has grown for some time. With navane, savé and ragi this difficulty does not occur, for the crop remains short throughout its entire growth. In order to allow for a more easy bagging in jola fields, it might be well to sow an outer strip of three yards with one of the shorter grains such as navane or ragi, so that the hoppers could be collected on this strip before

they got in on to the jola. This would, of course, be feasible only if the same type of spread takes place as was observed in 1910.

Finally, it must not be forgotten that a single bagging will not suffice to collect all the hoppers. A certain number will drop to the ground when the bag is drawn through the crop. Others will remain clinging to the stems. In addition, if bagging is begun early, as it should be, a number of the egg-masses will not have hatched. The work of bagging should, in fact, be looked upon in the same light as that of weeding, something which should be repeated at regular intervals. Just how many baggings will be necessary and what interval should intervene between the baggings will depend on a number of factors, first of which is the amount of co-operation that exists between the different raiyats and landholders in a village.

In the work that was done during the summer of 1910, the raiyat who saved his crop most completely carried out the bagging as many as eight times on his eight acres of jola. So many baggings would not have been necessary had his neighbours on all sides looked after their own crops. Some of these, however, bagged only twice. From a general consideration of the results obtained in 1910, it appears fairly certain that, if the operations are begun at the right time and carried out systematically throughout a whole village, three or four baggings are all that will be necessary.

Bagging operations in 1910 were confined to the lands of two villages—Hole-Madhapur and Devanayakanhalli, close to the town of Honnali. About sixteen acres in the area that had been worst infested by the grasshopper the previous year, were deep-ploughed to a depth of about eight inches with an improved plough. It was with the greatest difficulty that the raiyats of these villages were persuaded to take up the remedial measures and there were only one or two of them who did the work thoroughly and systematically.

On account of the apathy of the raiyats, the commencement of the general bagging operations was delayed till the 17th August, when some of the jola was already too high to be properly bagged. Previous to this only twenty-eight acres had been bagged. For an idea of the number of grasshoppers that can be caught by this method, Plate IV, Fig. 2, may be consulted. This represents part of the catch made

during about five hours' work with six bags and shows the contents of three kerosene tins (each four gallons) of the hoppers. As these hoppers were at that time not more than one-half inch in length the numbers caught were enormous. A calculation based on actual counts of definite small quantities of grasshoppers indicates that there were not less than twenty-seven lakhs of hoppers in this pile. Another catch recorded is five tins with three bags in seven and a-half hours (about forty-five lakhs of hoppers). When it is remembered that these hoppers were not more than one-third grown and that they would, if left, have lived at least two months longer, the damage that they would have been capable of doing can, to some extent, be imagined. Plate IV, Fig. 3, shows a photograph of the young hoppers feeding on jola, taken on the 17th August, the day on which general bagging operations were begun.

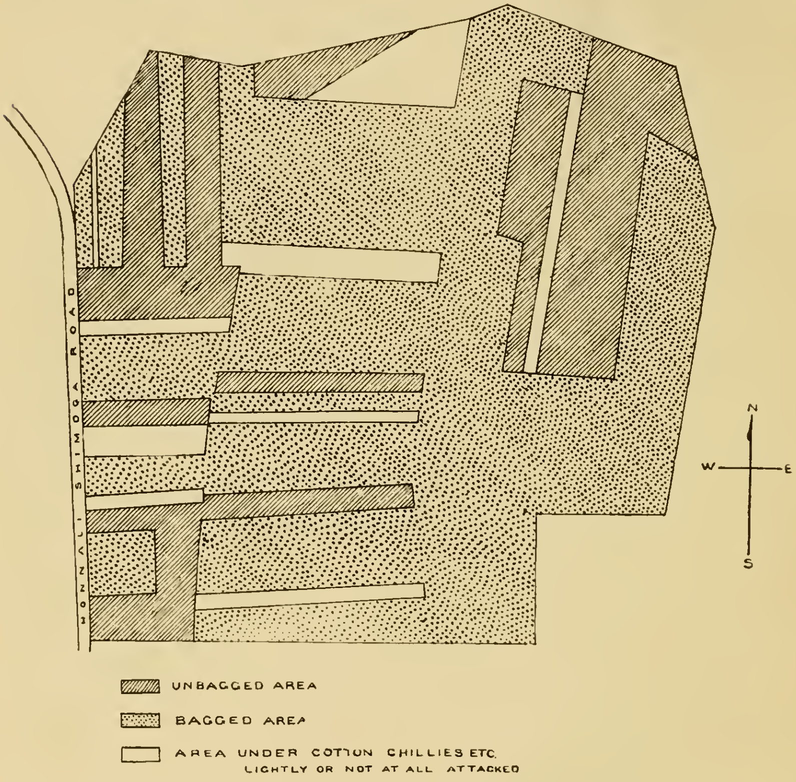
In a note prepared by Mr. Y. Ramachandra Rao, Assistant Entomologist, Madras, furnished through the kindness of Dr. C. A. Barber, Botanist to the Madras Government, the author states that bagging was tried in Bellary District, but was given up when it was found that only a small proportion of the hoppers actually present on the crop could be caught. This clearly does not agree with the results above noted, and information received from Bombay Presidency indicates that bagging was also quite successful there. In place of bags, the author then used a hopper trap, which he describes as follows:—"A set of three long shallow tin trays about six feet long were made and fitted with side pieces of stiff steel hoops. All the fields in Bellary District being drill-sown, the trays were placed between adjacent rows of plants and joined together by cross bamboo pieces. The interior of the trays was covered with tar. The trap was dragged along the rows by two ropes by two coolies. As the trap moved forward the side and cross pieces brushed past the leaves of the jola plants, and the hoppers being disturbed, jumped down into the tar where they were caught and killed." He further states: "This machine was convincing, but people in only three villages actually took it up. Even here they left it when they found hoppers coming in from neighbouring fields. In one place, Holagondi, the Gowda used it energetically and saved his jola, ragi, etc., at a cost of a little less than Rs. 2 an acre. This year it is proposed

to take up by blocks in two or three places and actually work out the cost, etc., of the method, improve it, if possible, and demonstrate to the people."

This method is decidedly ingenious and is undoubtedly worthy of trial. I believe, however, that it will hardly prove to show any advantage over bagging with a bag such as used in Mysore, if the work is done at the proper time. It probably would prove better if the jola had grown too high for effective bagging. On the other hand, the more complex nature of the apparatus, the greater cost of operation (the author does not state whether the cost of the pans is included in the estimated cost of operations per acre) and the additional fact that such an apparatus could not be used at all satisfactorily on grassy strips or patches, where the grasshoppers in the early stages of development are more numerous than on the crop itself, would indicate that the bag is likely to prove the more practical and effective implement of destruction.

As already stated, the bagging operations were carried out very unequally and the results in consequence varied considerably. On eight acres of the deep-ploughed area the operations were carried out most thoroughly, bagging being done eight times with the result that the crop was entirely saved. In 1909, the owner of this land had harvested only one-half candy (200 lbs.) from his eight acres, the rest of the crop having been destroyed. The crop harvested was worth Rs. 10 and hardly repaid him for the work done on the land. In 1910, he harvested twelve candies worth Rs. 240. The deep ploughing had reduced the expenses of weeding by Rs. 10 while the owner estimated the expenses attached to bagging the whole area at only Rs. 6-9, including cost of bag. This estimate may be somewhat low, but, in any case, not taking into account the saving in weeding expenses, the bagging and deep ploughing paid for themselves some twenty times over. If we take into account the saving in weeding expenses ordinarily incurred, we find that it more than covers the cost of the operations including the small extra expense of ploughing with an improved plough. It should be noted here that this eight acres was in the centre of the area most severely infested in 1909, so there can be no question with regard to the directly beneficial results of the operations.

The bagging operations were carried out over a total area of about three hundred and twenty acres (see Map, Text-fig. 8). Although the work was not so thoroughly done on the rest of the area, a comparison of those parts where the least satisfactory results were obtained with a similar area untreated showed that, even in this case, the bagging had been decidedly profitable. The photographic plates at the




TEXT-FIG. 8.

Map of area in the villages of Hole-Madhapur and Devanayakanhalli on which bagging operations were carried out during the summer of 1910. The number of times bagging was done on the various portions could not be shown. The map was prepared from a sketch made by Agricultural Inspector B. C. Shantappa.

end of the text serve to illustrate the effect of bagging. Plate V, Fig. 1 shows part of a jola field in Devanayakanhalli where the attack was very severe and where nothing whatever was done to combat the pest. The stalks have been practically denuded of leaves, only the stiff midribs remaining. Practically no grain has been left in the heads and the crop is not worth harvesting

except as fodder. Plate V, Fig. 2 shows portion of a field in the same village not quite so badly attacked. The soil here is reddish. A few shreds of leaves have been left and the heads still contain a certain quantity of grain. This field was also untreated. Plate VI, Fig. 1 shows portion of a field which was deep-ploughed and bagged only twice. The seed was planted far apart in this field, hence the somewhat thin nature of the crop. The crop here has been for the most part saved, but this is partially to be accounted for by the fact that the neighbours of the owner on all sides, bagged more thoroughly than he did and hence helped to save his crop. As will be seen in the picture, the leaves have not been severely eaten while the heads have lost comparatively few grains. Plate VI, Fig. 2 shows a few jola plants in the most thoroughly-treated field. Here, as already stated, the crop has been practically completely saved. The field shown in Plate VI, Fig. 1 shows up in the back ground.

Data have been collected which allow us, with a considerable degree of accuracy, to estimate the probable cost of bagging for the Jola Grasshopper. In the bagging operations at Honnali, 1910, twenty-eight acres were handled by the department for three separate baggings made at intervals of about a week. For this work four men, on an average, were used on a single bag so that they could work in relays. It is doubtful if this was necessary, and I believe that at the most three men would be required to handle a bag. They could relieve each other at intervals, while the man who was resting could move the kerosene tin about for the gathering of the hoppers. It is possible that two men at a bag would be still more economical. This is the way the raiyats themselves arranged the work, for the most part.

It is well, however, to take the upper limit in calculating the expense, so we shall consider the expense of four men working with one bag. These men took about seven days to complete the work, doing, on an average, four acres in a day. At the end of each sweep the same ground was gone over again ; so each treatment was really a double one. During the first week, the men were paid at the rate of three annas a day each ; for the subsequent work, they were paid at the rate of four annas. If we take this higher figure, we get a total expense of seven

rupees for one complete treatment of the twenty-eight acres. Supposing four treatments at intervals of a week to be necessary, we have a total expenditure of Rs. 28 for the twenty-eight acres, or at the rate of one rupee per acre. If we take into account the cost of the bag and fix it at the high rate of two rupees, the expense per acre would be increasd by about one anna.

In the majority of cases, a raiyat would not have as much as twenty-eight acres, so that the expense per acre would be slightly more on account of the initial outlay for the bag. The bag would, however, in neither case be worn out and the material could be used for other purposes, or the bag could be kept for another year's work.

It seems safe to say that the expenses connected with bagging operations will hardly exceed one rupee per acre where co-operation exists and the work is done at the right time. There is no reason why this work cannot be done by boys, in which case the bag might be made somewhat smaller. The expenses would be thereby reduced and, where the work is done by members of the raiyat's own family, the actual money outlay would be simply for the purchase of materials to make the bags.

## GENERAL CONCLUSIONS.

1. The Jola or Deccan Grasshopper is a new pest which has probably entered Mysore from Dharwar District, Bombay Presidency. It first appeared in Mysore four or five years ago, and has been becoming each year more destructive.

2. The grasshopper has already appeared in areas of Honnali and Channagiri Taluks, Shimoga District, and of Davangere, Jagalur and Chitaldrug Taluks, Chitaldrug District. The total area infested is between 15,000 and 20,000 acres.

3. Although this insect cannot fly, there is great danger of its being spread by means of carts travelling from infested to uninfested districts. It is, moreover, quite capable of spreading slowly of its own accord, so, unless energetic measures are taken to check it, it is likely gradually to spread throughout the State wherever dry land cereals are grown.

4. This pest feeds on the leaves and grains of practically all dry land cereals grown in the State. It also feeds upon the leaves and flowers of leguminous crops and to a very slight extent on chillies and cotton. Up to the present, the damage to these latter crops has been negligible, but it is quite possible that, should it be deprived of other food, it might do great damage to these crops also.

5. Eggs are laid in the soil of the fields as well as in land bordering them, in November and December. The eggs hatch during the following July and August. The insects require from two and a-half to three and a-half months for development.

6. While there are a few natural enemies which feed upon the eggs and the grasshoppers, these cannot be relied upon to keep the pest in check.

7. It is possible that careful ploughing early in the season to a depth of four inches, together with thorough cultivation afterwards, may lead to a large destruction of the eggs, but this has not, as yet, been proved.

8. Deep ploughing with an improved plough to a depth of eight or nine inches buries numbers of the egg-masses so deep that the young hoppers are not able to emerge. A thorough test of this method must be made on a fairly large scale before definite conclusions can be reached as to its efficacy.

9. The catching of the young hoppers by means of bags swept over the crop has proved a very efficient means of keeping the pest in check. It should be begun not later than the beginning of August, and should be repeated three or four times or even more. For the best results, all the raiyats and land-owners in the infested tracts must co-operate. The work should be considered a part of the cultural operations more important even than weeding and should be done with the same care and repeated with the same regularity. The appearance of grasshoppers in the fields after the first bagging is to be expected just as much as the appearance of weeds after the first weeding. Here, as in other agricultural operations, only persistent and repeated labour is likely to yield good results. The expenses of bagging should not exceed Re. 1 per acre, provided the necessary co-operative effort is made.

In conclusion, it must be emphasized that the recom-

mendations as to combative measures presented here apply especially to Mysore. While they may be considered to apply, in a general way, to the whole infested area, it is quite probable that they may be more difficult to carry out and also less remunerative elsewhere. If, for instance, large areas of waste and grass land occur in infested regions, it is clear that the difficulty of combating the pest would be greatly increased. In such a case, it would be necessary to carry out the operations on the waste as well as on the cultivated land and this would, of course, increase the cost very much. This does not apply to the infested areas in Mysore, for, up to the present, the grasshopper has been confined to areas where practically no waste land occurs. A second point which should be remembered is that in Mysore the infested areas have as chief cereal crop, jola, a cereal which, with a normal yield, is more profitable than most of the other dry land cereals, such as navane, sajje and savé. The crops in Mysore are, therefore, sufficiently remunerative to warrant an outlay very much greater than that which is necessary to combat this pest.

I have deemed it necessary to add the above explanation from the fact that there is no commoner mistake than that of attempting to apply the results obtained in one place and under one set of conditions to other localities and conditions which may be decidedly different in their nature. Remedial measures, to be of any certain value, must be worked out with a knowledge of local conditions and with a view to suit those conditions in the most intimate manner possible.

## EXPLANATION OF PLATES III—X.

[The drawings reproduced on Plates VIII—X were made with the aid of the Abbe camera lucida.]

### *PLATE III.*

FIG. 1.—Photograph of healthy head of jola (*Andropogon sorghum*, L.).

FIG. 2.—Photograph of jola head damaged by the Jola Grasshopper. Only a few grains have been left.

(Figs. 1 and 2 are both reduced to about the same extent.)

### *PLATE IV.*

FIG. 1.—Bags at work in jola field. Photographed Honnali, August, 1910.

FIG. 2.—Part of one day's catch of young hoppers with six bags. The heap contains about twenty-seven lakhs of hoppers. Photographed Honnali, August, 1910.

FIG. 3.—Nymphs of Jola Grasshopper feeding on young jola. Photographed Honnali, August, 1910.

### *PLATE V.*

FIG. 1.—Part of untreated jola field near Honnali almost completely destroyed by the Jola Grasshopper. Photographed December, 1910.

FIG. 2.—Part of untreated jola field near Honnali attacked by Jola Grasshopper but not so completely devastated as the field shown in Fig. 1. Note the extensive growth of weeds, owing to weeding operations being neglected. Photographed December, 1910.

### *PLATE VI.*

FIG. 1.—Part of field near Honnali which was deep-ploughed and bagged twice. No weeding was done, so this should be compared with Plate V, Fig. 2. The thinness of the crop is due to wide planting. Photographed December, 1910.

FIG. 2.—Clump of jola plants in field near Honnali which was deep-ploughed and bagged eight times. The crop is almost completely saved and the heads are very fine. Photographed December, 1910.

### *PLATE VII.*

FIG. 1.—Female Jola Grasshopper laying eggs in breeding cage.

FIG. 2.—Egg-mass of Jola Grasshopper removed from breeding cage. The covering matter has been removed from one side to show the natural arrangement of the eggs.

FIG. 3.—Egg-mass of Jola Grasshopper in lump of black cotton soil removed from infested field near Malebennur. Above the eggs, as well as surrounding them, is to be seen the brown spongy cement material poured out as a froth by the female during egg-laying.

FIG. 4.—Nymph of Jola Grasshopper in the act of hatching. The egg-shell still surrounds the posterior end of the body and the insect is still inclosed in the amnion.

FIG. 5.—Empty egg-shells with amnia in them. In the centre one, can be seen the two holes in the amnion from which the front pair of legs have been withdrawn.

FIG. 6.—Blister beetle larva with head buried in an egg-mass of the Jola Grasshopper. The larva is feeding on the eggs.

FIG. 7.—Larva of blister beetle removed from egg-mass.

FIG. 8.—Syrphus fly found preying on nymphs of the Jola Grasshopper.

FIG. 9.—Mass consisting almost entirely of fragments of the skeleton of the Jola Grasshopper cast out by the common pariah kite (*Milvus govinda*, Sykes).

## *PLATE VIII.*

FIG. 1.—Thorax of nymph of *C. sphenarioides* in first instar; (*a*) prothorax, (*b*) mesothorax, (*c*) metathorax here and in following figures.

FIG. 2.—Thorax of nymph in second instar.

FIG. 3.—Thorax of nymph in third instar. The first signs of development of the wing-bud are to be seen on the mesothorax.

FIG. 4.—Thorax of nymph in fourth instar. Development of wing-buds is now apparent on both meso- and metathorax.

FIG. 5.—Thorax of nymph in fifth instar. The wing-buds have both become turned up.

FIG. 6.—Thorax of nymph in the sixth instar. Anterior wing-bud (that of elytron or wing-cover) has grown backward almost to posterior edge of metathorax.

FIG. 7.—Thorax of adult male of *C. sphenarioides* showing the elytron in its permanent condition.

FIG. 8.—Antenna of nymph of first instar.

FIG. 9.—Antenna of nymph of second instar.

FIG. 10.—Antenna of nymph of fourth instar.

FIG. 11.—Antenna of nymph of sixth instar.

## *PLATE IX.*

FIGS. 1–6.—Development of posterior end of female *C. sphenarioides*; (1) first instar, (2) second instar, (3) fourth instar, (4) fifth instar, (5) sixth instar, (6) adult from side.

FIGS. 7–12.—Development of posterior end of male *C. sphenarioides*; (7) first instar, (8) second instar, (9) fourth instar, (10) fifth instar, (11) adult from beneath, (12) adult from side.

## PLATE X.

FIG. 1.—Basal portion of antenna of adult male of *C. sphenarioides* viewed from the side.

1*a*. Transverse section of third segment.

1*b*. Transverse section of fifth segment.

1*c*. Transverse section of seventh segment.

FIG. 2.—Basal portion of antenna of female *C. sphenarioides* viewed from the side.

2*a*. Transverse section of third segment.

2*b*. Transverse section of fifth segment.

2*c*. Transverse section of seventh segment.

FIG. 3.—Inner surface of dorsal wall of first abdominal segment to show dorsal gland in position. Between it and the dorsal wall lie the longitudinal muscles which move one segment on the next.

FIG. 4.—Dorsal wall of first abdominal segment viewed from within. The gland is turned back on to the second abdominal segment.

FIG. 5.—Portion of grasshopper viewed from above to show the gland shining through the dorsal wall and its opening on the articular membrane between the first and second abdominal segments.

PLATES.

*Plate III.*

*Fig. 2*

*Fig. 1*

FIG. 1

FIG. 2

FIG. 3

Plate V.

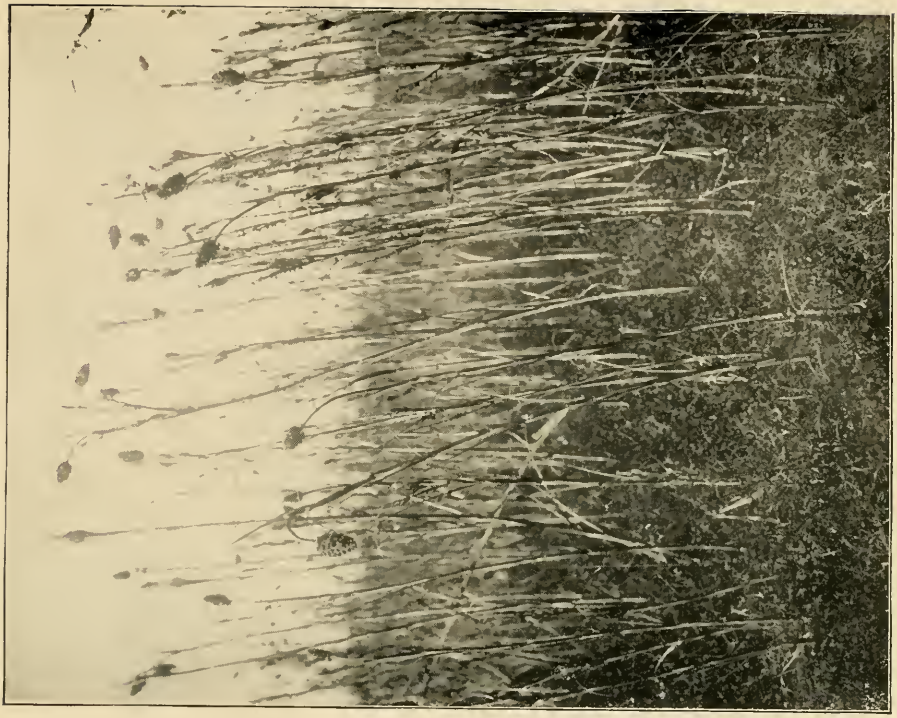


Fig. 2

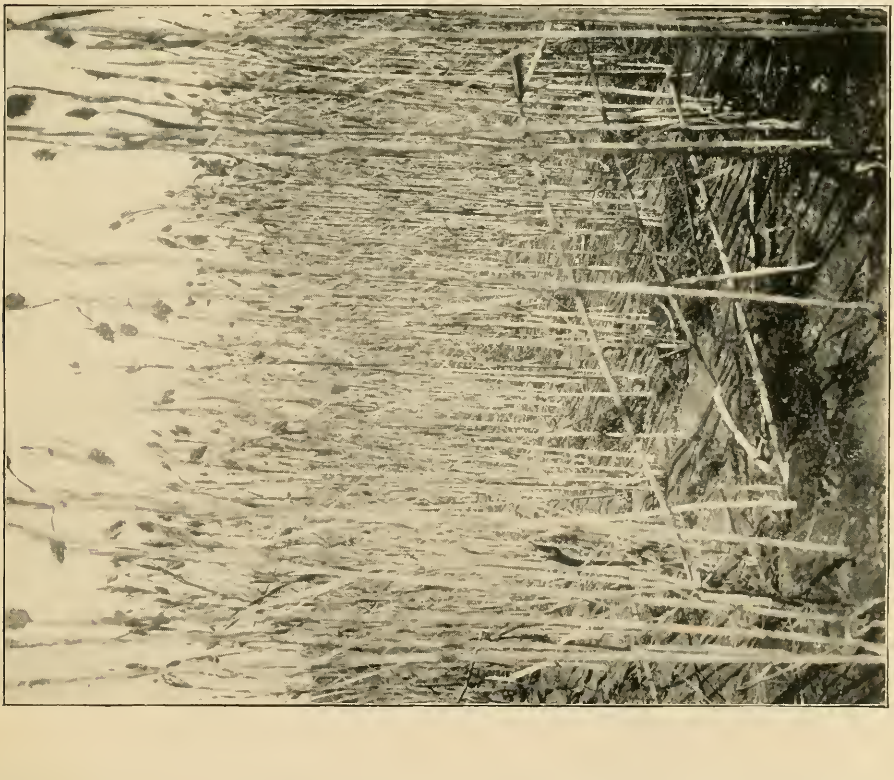


Fig. 1

Plate VI.

Fig. 2

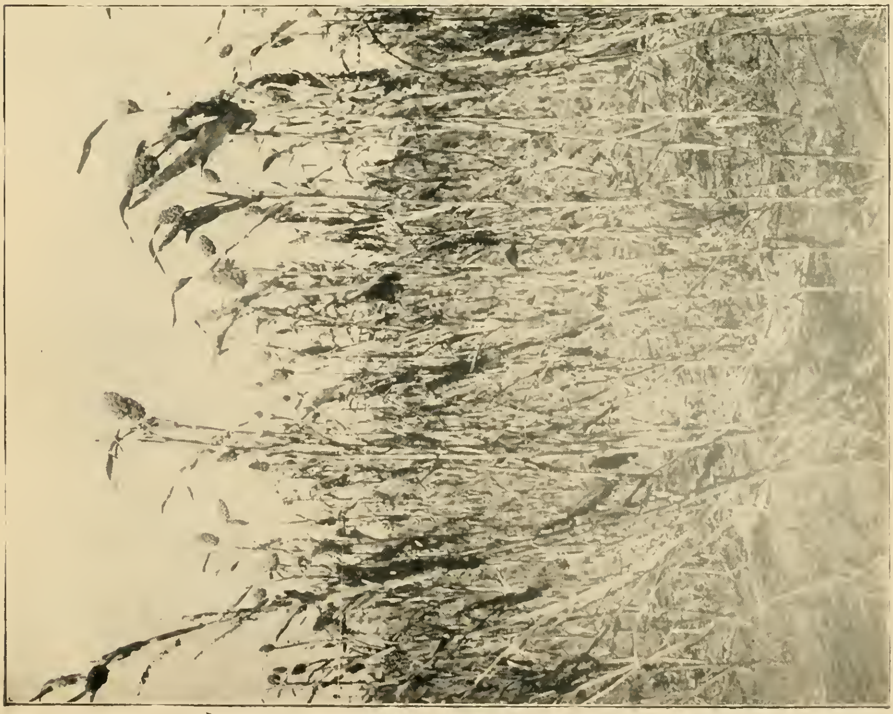


Fig. 1

Plate VII.

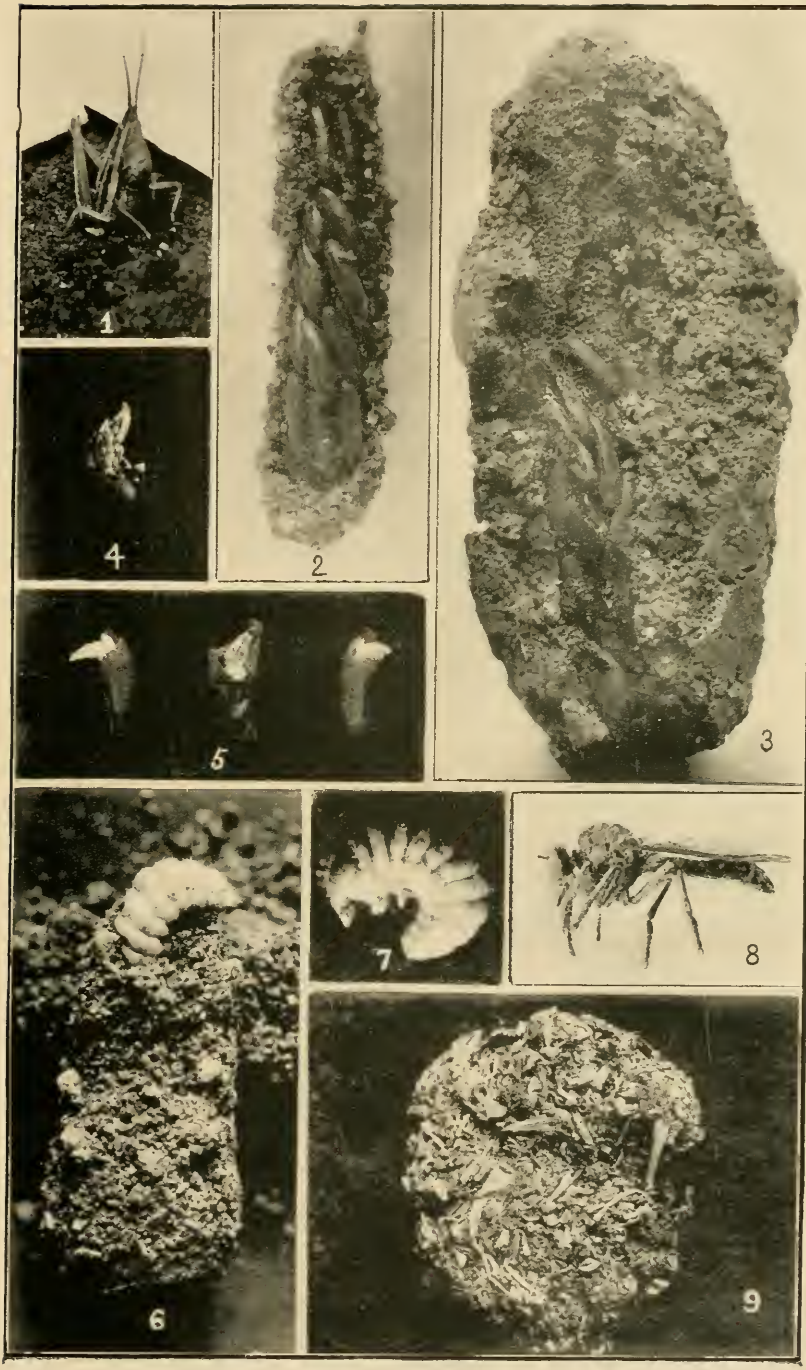
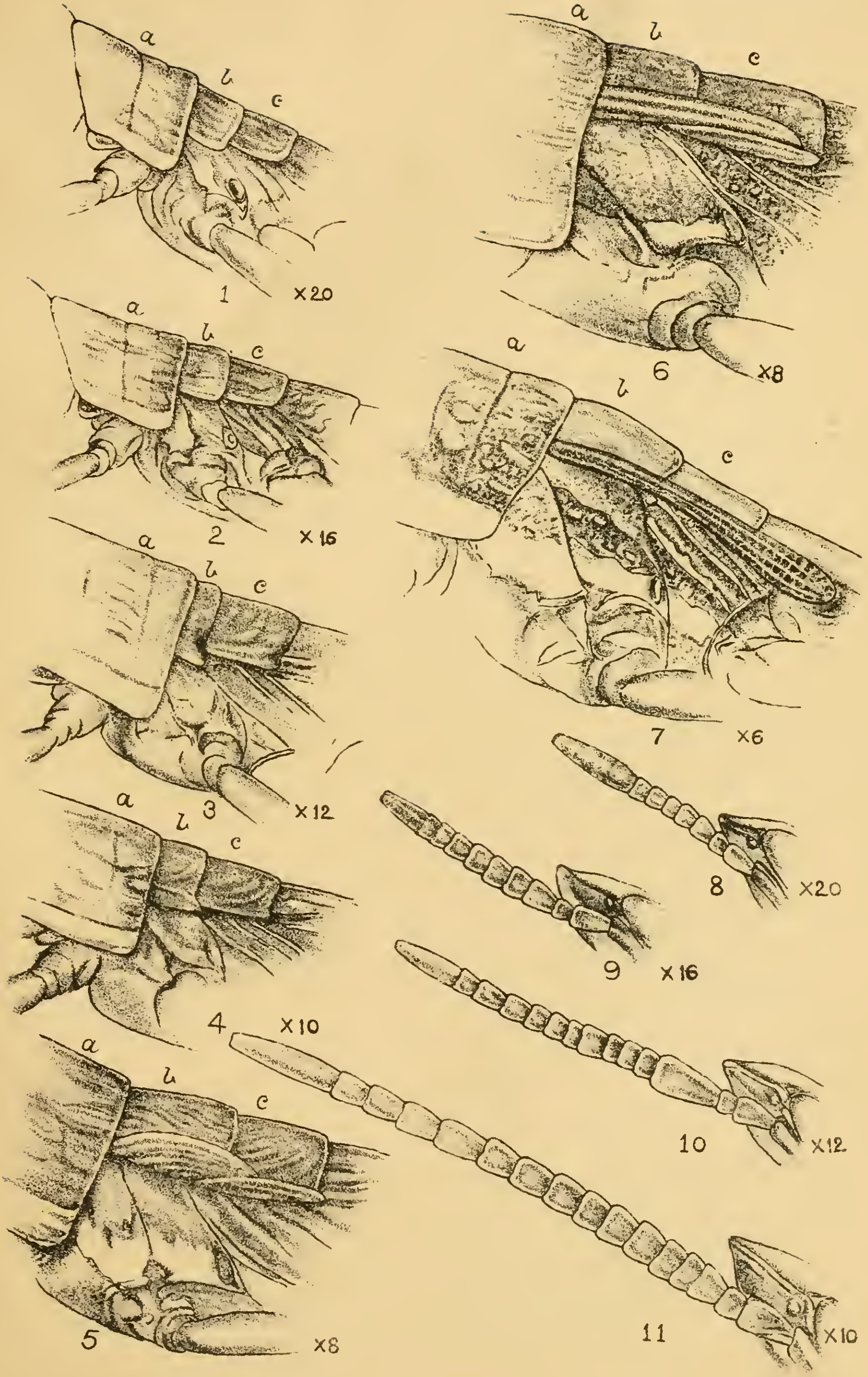


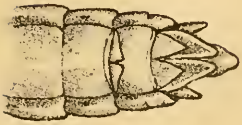
Plate VIII



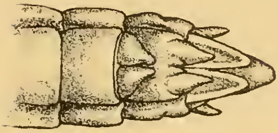
a
b
c
1
X 20
a
b
c
2
X 16
a
b
c
3
X 12
a
b
c
4
X 10
a
b
c
5
X 8
a
b
c
6
X 8
a
b
c
7
X 6
8
X 20
9
X 16
10
X 12
11
X 10

*Plate IX*

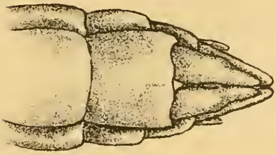
1 ×20



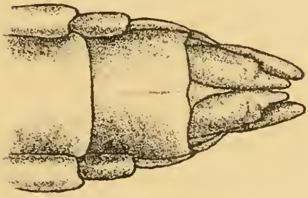
2 ×16



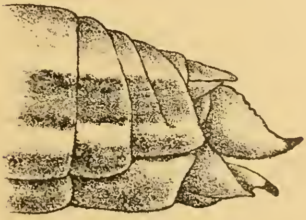
3 ×12



4 ×8

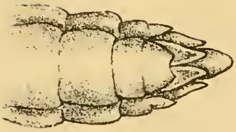


5 ×6

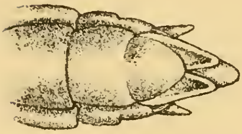


6 ×6

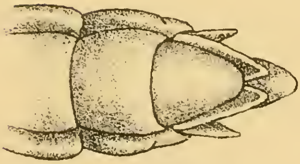
7 ×20



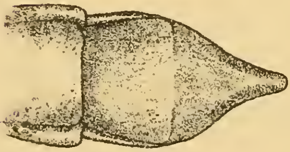
8 ×16



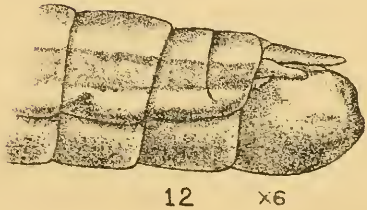
9 ×12



10 ×8

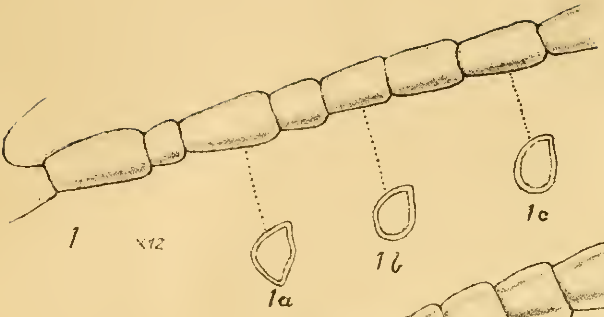


11 ×6

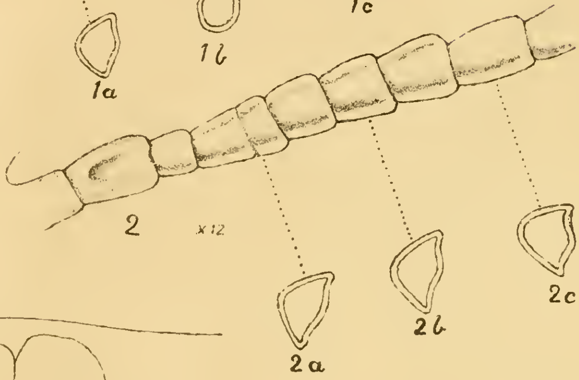


12 ×6

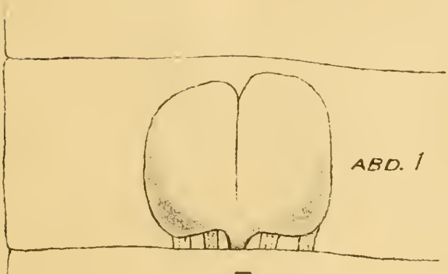
## Plate X




1 ×12

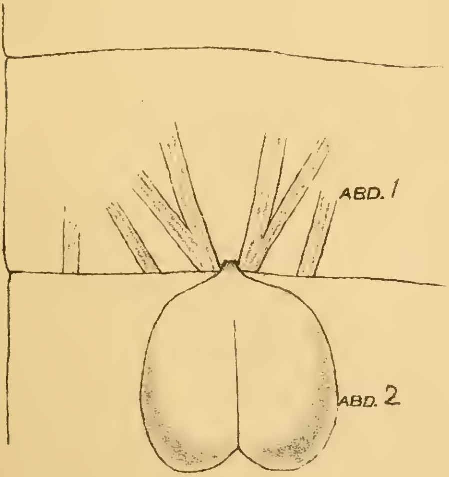



2 ×12

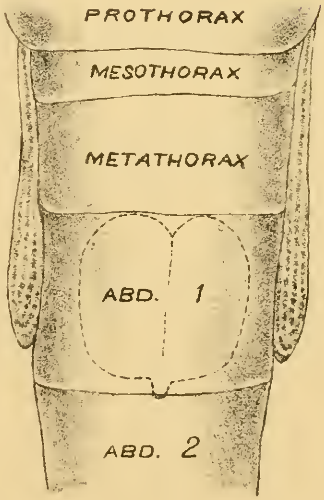



3 ×8

ABD. 2




4 ×8




5 ×8